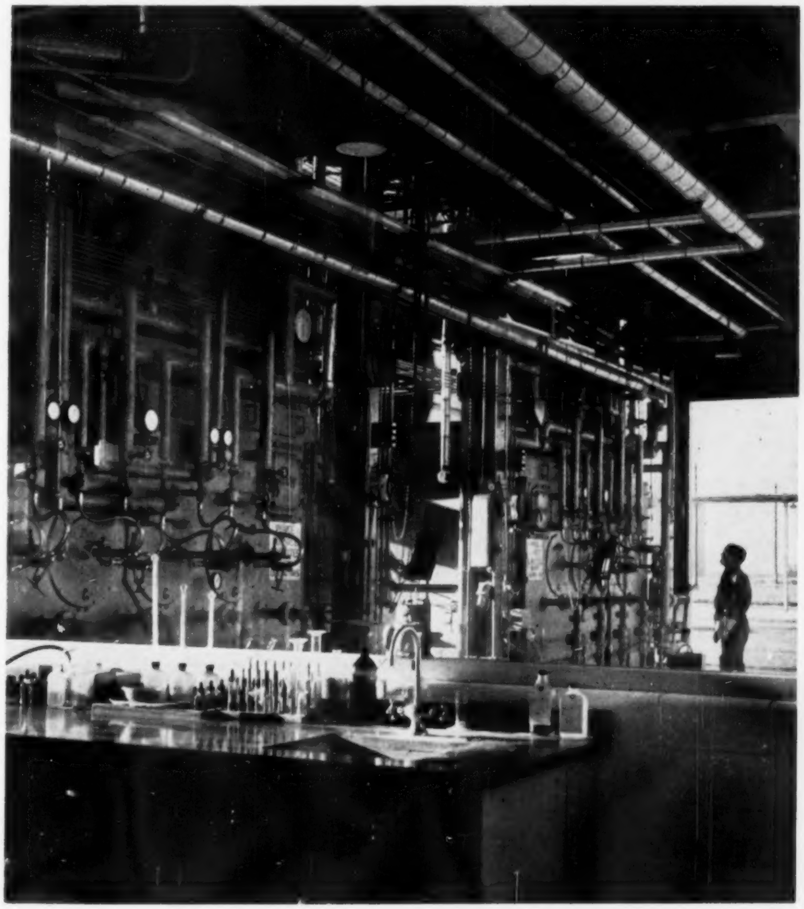
Combustion

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION



Modern boiler room interior, see page 2

March 1960

Testing Air Preheaters

Economics of Operation and Replacement

Boiler Safeguards Forum

Steam Power Plant Clinic

Combustion

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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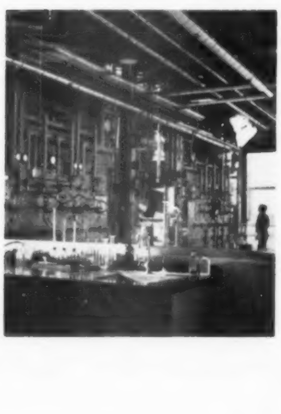
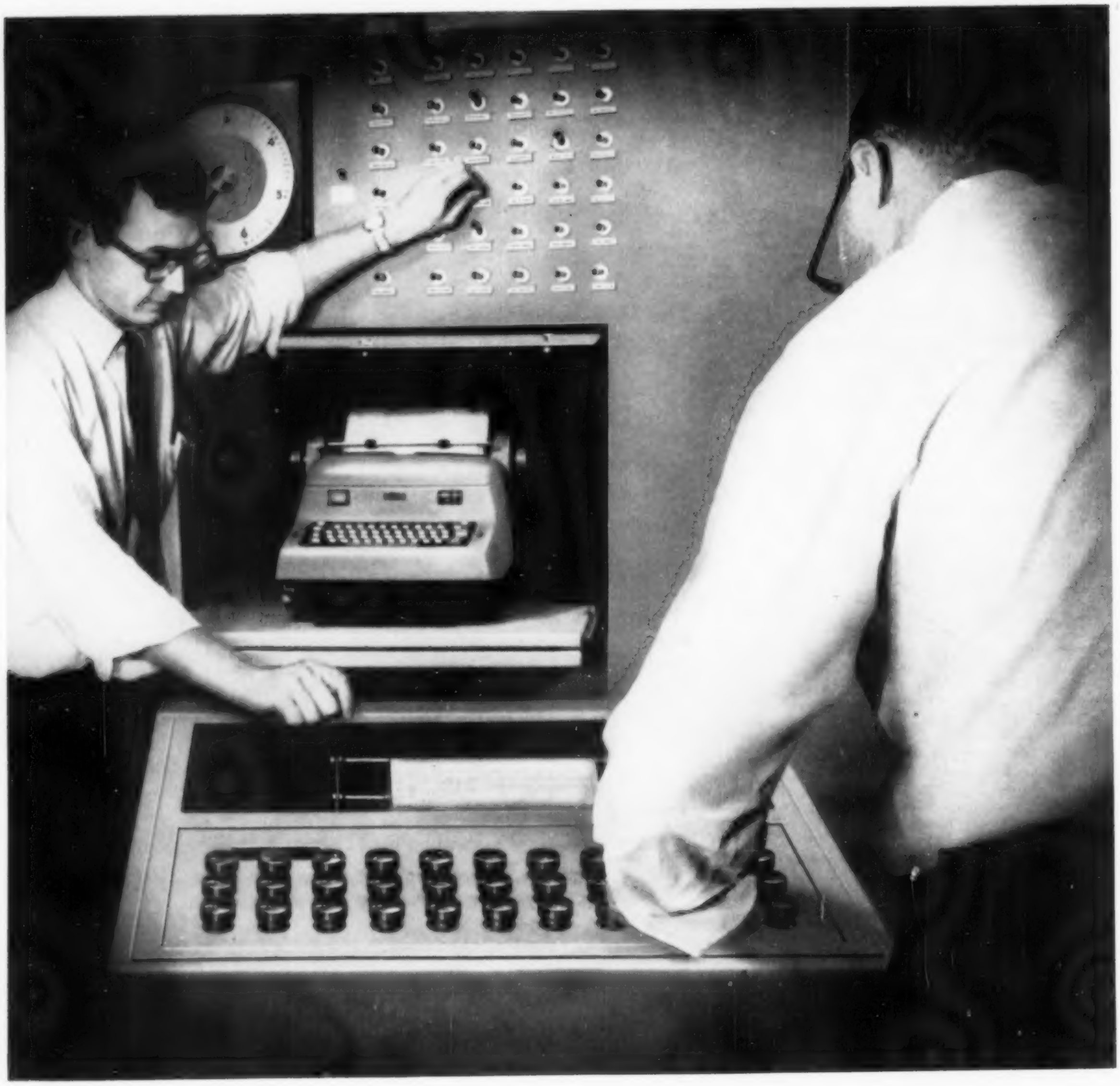
BPA

Printed in U. S. A.

Free use of space and environment in modern boiler room is characterized by the cover view of the installation at the Procter & Gamble Co. plant, Sacramento, Calif., see page 42.





1200 Temperatures entrusted to two L&N data systems!

At the new Bergen Generating Station of Public Service Electric and Gas Company, two 600 point L&N Data Systems will monitor bearing, boiler tube, and condensate temperatures for No. 1 and 2 Units.

Electric typewriters will log data for each unit on continuous 8½" wide log sheets, perforated every 11" . . . one typewriter logging all 600 temperatures while the other is recording off-normals (in red) and up to 10 trends. All inputs are scanned every two minutes for off-normals, with scanning proceeding during logging and trending. As an example of the system's safety measures, all data can go through either typewriter so the operator is never left without vital information.

In designing this system, Public Service and L&N engineers made a thorough study of Bergen's requirements. L&N's contribution was based on 30 years' experience in power plant measurements and an expert knowledge of data processing. For data systems and other power plant controls, call your nearby Field Office or Leeds & Northrup Co., 4972 Stenton Ave., Philadelphia 44, Pa.

Data Systems engineered to power-plant standards by **LEEDS & NORTHRUP**
Instruments · Automatic Controls · Furnaces

Control room at Shippingport Atomic Power Station. Bailey Instruments for the primary system and Bailey Instruments and Controls for the steam system are located on this control panel.

Bailey pioneers the control of . . .
ATOMIC STEAM POWER PLANTS

This control room is the center of operations for the world's first full-scale atomic, electric power plant devoted exclusively to civilian use—the Shippingport Station, jointly owned by Duquesne Light Company and the Atomic Energy Commission.

Here, as well as on the atomic-powered submarines, are Bailey Instruments and Controls performing dependably hour after hour, month after month.

In conventional power plants, too, Bailey Meters and Controls are standard equipment. Bailey is the choice of virtually all the most efficient plants on the Federal Power Commission's heat rate report. Here's why:

1. A Complete Line of Equipment

You can be sure a Bailey Engineer will offer the right combination of equipment to fit your needs. Bailey manufactures a complete line of standard compatible pneumatic and electric metering and control equipment that has proved itself. Thousands of successful installations involving problems in measurement, combustion and automatic control are your assurance of the best possible system.

2. Experience

Bailey engineers have been making steam plants work efficiently for more than forty years. Veteran engineer and young engineer alike, the men who represent Bailey, are storehouses of knowledge on measurement and control. They are up-to-the-minute on the latest developments that can be applied to your problem.

3. Sales and Service Convenient to You

There's a Bailey District Office or Resident Engineer close to you. Check your phone book for expert engineering counsel on your steam plant control problems.

A136-1

Instruments and controls for power and process

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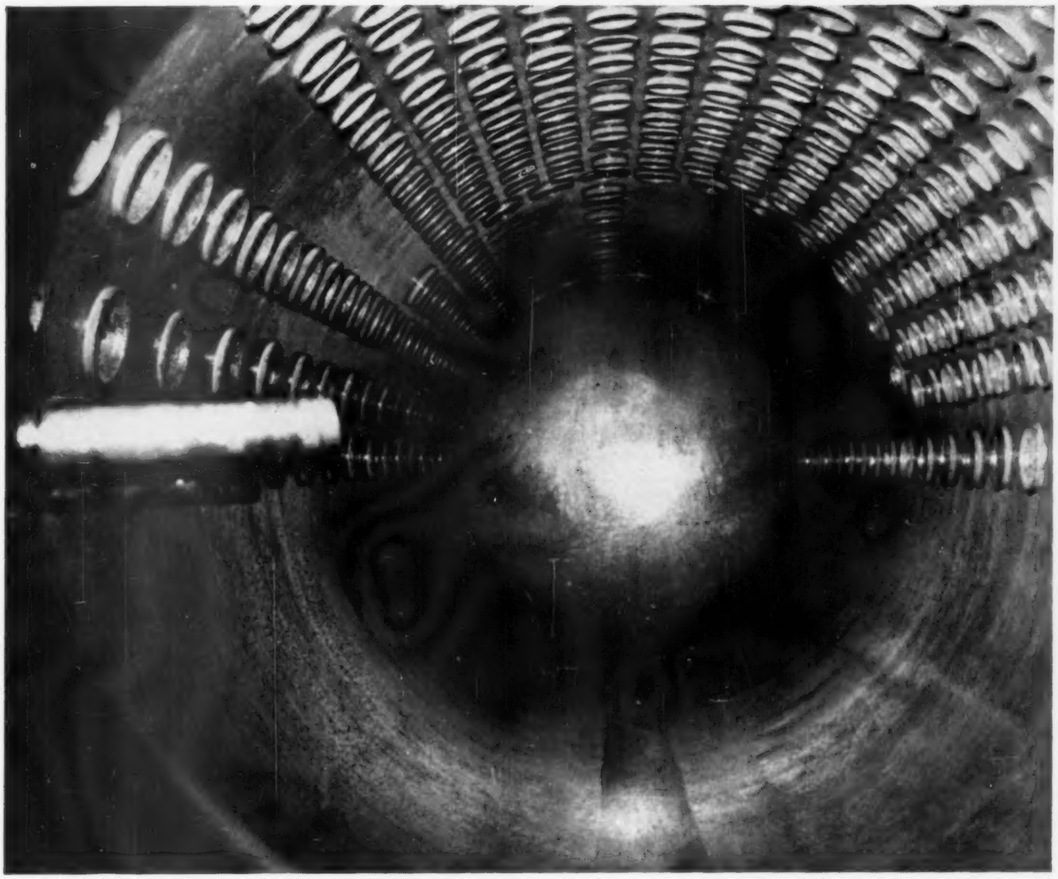
In Canada—Bailey Meter Company Limited, Montreal



No Sludge . . . No Scale . . . No Corrosion in this boiler

Opened for inspection, this large boiler drum shows the results of a year's attention to good water treatment: *nothing!* No sludge, no scale, no corrosion . . . Ready to go back on line without even a wash-out . . . Down time and maintenance minimum, fuel economy and operating efficiency tops . . . Thanks to The Nalco System of Water Treatment, and good plant control practices.

Nalco System treatment includes proper water treating chemicals *plus continuing Nalco service* that assures effective protection for your steam and water system—from raw water intake through condensate return lines.

For prompt action and straightforward assistance on any water treatment problem, call on Nalco.

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- OIL WELL AND REFINERY CORROSION CONTROL

THE Nalco® SYSTEM . . . SERVING INDUSTRY THROUGH PRACTICAL APPLIED SCIENCE

Hall Industrial Water Report

VOLUME 8 | MARCH 1960 | NUMBER 2

How to Increase Your Salary

Water's insatiable appetite for iron and other commonly used metals and alloys is costing industry many millions of dollars every year. Effective treatment of water to reduce corrosion to a minimum can save a substantial chunk of these dollars and route them into the till. Thence into the stockholder's pocket as dividends and into your pocket as a reward for cutting costs.

Hall engineers know how to treat water to combat its attack of metals. They can help you save many of the dollars that are being spent for maintenance and repairs because of avoidable corrosion.

Elusive Oxygen

Sodium sulfite feed for chemical fixation of residual dissolved oxygen in the boiler feedwater at a southern paper mill is usually less than twenty pounds per day. A sudden threefold jump in the requirement puzzled the operators. The increase in dissolved solids necessitated more blowdown which, in turn, increased requirements for other water conditioning chemicals.

When Hall engineer T. W. Hubner was called in, the symptoms indicated either trouble in the deaerating heater or bypassing of the heater with water high in dissolved oxygen. The second possibility was the easier to check.

A search by the operators then located the trouble. A valve in a bypass line was partially open which accounted for the difficulty. When the valve was closed, water conditions returned to normal. Experience enabled Hubner to steer the search in the right direction.

Luxury Pays Off

An aluminum fabricator was forced to reduce production several times per year for removal of corrosion products from inert gas coolers. Water treatment to control the corrosion in the cooling system had been considered. However, the operation was a small one and it was felt that water treatment was a luxury.

Hall engineers surveyed the cooling water problem and found that the cooling system could be protected at a cost of less than sixty cents per day.

Results have confirmed the findings. The annual cost of water treatment, which now permits uninterrupted production, is less than the previous cost of a single heat-exchanger outage.

Unusual Corrosion Problems

Peculiar corrosion effects sometimes result from contact of acid and steel. They are of interest because they might be encountered in connection with acid cleaning or in equipment used to store and handle acid for water treatment.

Although the rate of reaction between 66° Baume sulphuric acid and steel is substantially nil, it is greatly accelerated if moisture is picked up from the atmosphere. Bubbles of hydrogen, generated by corrosion, presumably become detached from the metal, rise and accumulate in contact with metal at such locations as horizontal pipe. Resulting erosive and galvanic effects impair the normal protective oxide coating. Narrow, but sometimes deep, grooves can be produced.

Hydrogen blistering has been observed near or just above the liquid level in concentrated sulphuric acid storage tanks and in pickled steel. Atomic hydrogen from corrosion diffuses through the metal. Where the hydrogen atoms meet something that catalyzes the formation of molecular hydrogen, the larger molecules cannot pass on through the metal. Accumulation of gas occurs and pressure becomes high enough to tear apart the metal grains. Failure tends to proceed along planes of stress which are predominantly parallel to the surface in steel plate, so characteristic gas blisters result.

Rain Water in Compressor Coolers

Decreasing supplies of surface and ground water in eastern gas fields have forced compressor operators to rely heavily on rain water storage to provide water for cooling system makeup. This has resulted in rapid corrosion of black iron pipe and formation of heavy organic deposits on heat-exchange surfaces.

Hall engineers were handed a tough assignment. Prevent corrosion and deposits in closed systems of steel, cast iron and copper containing a naturally aggressive water contaminated with oil, saturated with oxygen, at high temperature—and do this economically.

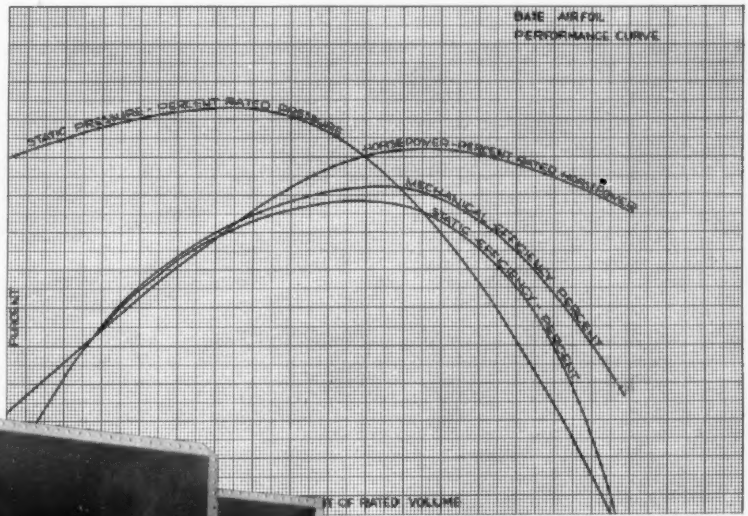
A corrosion inhibitor of the borax-sodium nitrite type, containing a special inhibitor for copper (Hagan Corrosion Inhibitor CS) has provided the answer. Current corrosion rates of both copper and iron are of the very low order of 1 mg/dm^2/day. Chemical cost is about 25 percent of what it was originally. A bonus is emulsification of the organic material by the inhibitor with less accumulation of deposits on the heat-exchange surfaces.

Water is your industry's most important raw material. Use it wisely.

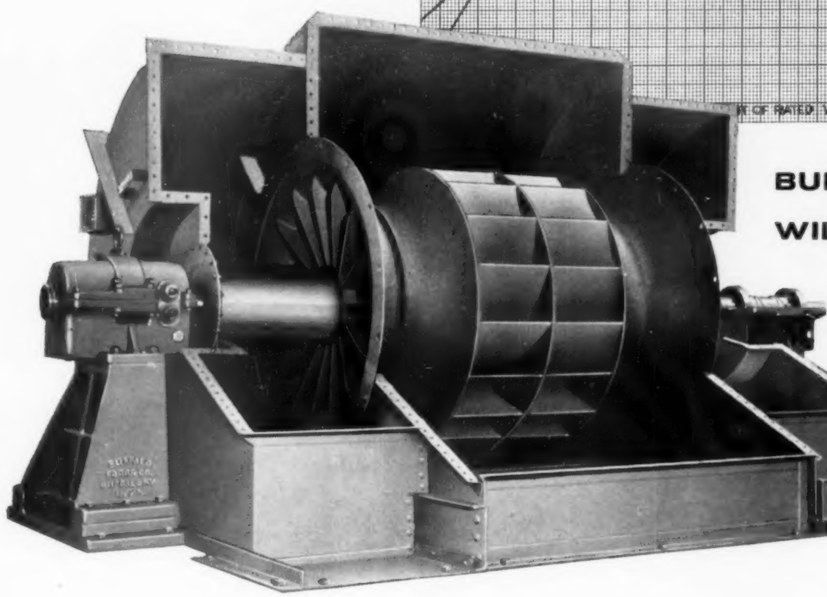
Industrial Water Problems Require Special Handling

There are no "stock answers" to industrial water problems. For information on how the Hall System can help you solve your particular water problems, write, wire or call address below.

PLAN TO OPERATE AT FULL RATED CAPACITY OVER EXTENDED PERIODS?



Performance curve of a Buffalo type "BA" Airfoil Fan shows how static efficiency curve peaks in the designed operating range of the capacity—pressure curve.



BUFFALO AIRFOILS WILL HANDLE THE JOB MOST ECONOMICALLY

Extreme high efficiency between 85 and 110% of rated volume — top performance against high static pressures — make the Buffalo Type "BA" Airfoil your best selection for continuous, full-capacity draft service. Its streamlined inlet bell and matching wheel flange form a smooth, path for easiest air flow into the wheel. Its aerodynamically formed airfoil blade channels provide optimum air passage thru the wheel; while the unique design diverging outlet permits best static regain from cutoff.

And the Type "BA" Airfoil is one of a full line of Mechanical Draft Fans to fit today's widely varying requirements — each built to the famous "Q" Factor* of excellence. For full details on the best draft fan for your money and your job, write for Bulletin FD-905.

**The "Q" Factor—the built-in Quality which provides trouble-free satisfaction and long life.*

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VENTILATING • AIR CLEANING • AIR TEMPERING • INDUCED DRAFT • EXHAUSTING • FORCED DRAFT • COOLING • HEATING • PRESSURE BLOWING

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We've hit a BRAND-NEW vein of that high BTU, low ash ZEIGLER Coal!

Ask any old-timer about that wonderful, clean-burning coal from the old Zeigler No. 1 mine. He'll tell you it was the hottest, best-liked fuel on the market.

Well, the *original* is back . . . better than ever, and it's SUPERWASHED and wax treated, of course.

Recommend ZEIGLER Superwashed Stoker Coal to your customers. They're bound to like it.

Order now for prompt delivery in time for the heating season

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St. Louis • Minneapolis • Omaha • Louisville
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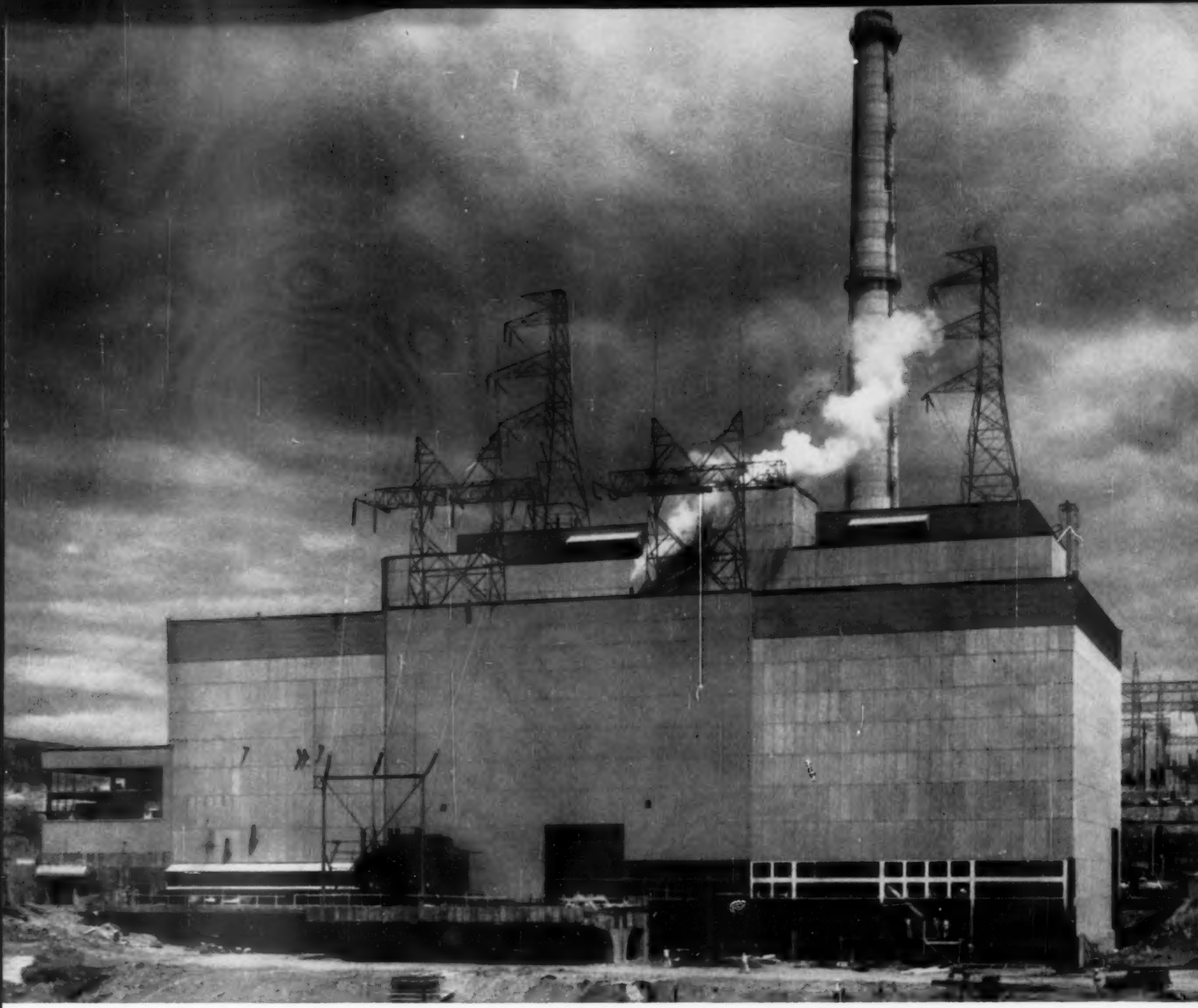


PEPCO DICKERSON #1 ON THE LINE: UNIT #2 COMING SOON

Unit #1 of the new Dickerson Station of Potomac Electric Power Company went on the line in June 1959. A second duplicate unit is scheduled for service in early 1960. This modern station was designed and constructed by Stone & Webster Engineering Corporation in conjunction with the Engineering Departments of PEPCO. Major fluid handling equipment furnished by Worthington includes the condensers, circulating water and condensate pumps, rotative dry vacuum pumps, boiler feed and booster pumps, and main deaerators to supplement condenser deaeration in protecting the boilers and feed cycle.

The fluid handling equipment for each unit incorporates a number of special features. Included is the power-saving technique of a single full capacity boiler feed pump driven from the main turbine generator shaft through a variable speed coupling, with a spare turbine driven feed pump. Use of booster pumps also permitted mounting the main deaerator on the turbine room floor, thus minimizing cost of supporting structure and piping.

The condenser serving each unit is 110,000 sq. ft. two-pass, of special construction for maximum deaeration. It is rigidly mounted with rubber belt-type expansion joint in the turbine exhaust connection, and equipped with built-in reverse flow valves for periodic backwashing. The separate screenhouse at the river contains four circulating water pumps of vertical single suction volute MIXFLO dry pit type, driven by two-speed induction motors, supplying 95,000 gpm to each unit.

As a manufacturer of major steam cycle fluid handling equipment, Worthington has a reservoir of "system-wise" experience available to help in your power planning projects. For information, call your nearest Worthington District Office. Or, write to Worthington Corporation, Section 45-15, Harrison, New Jersey.

WORTHINGTON

The Story of Edward Research

and the Leak-proof Valve

In the early 1940's, the advance of steam power plant pressures and temperatures demanded a leak-proof, small sized valve—one with permanent tightness at the seat joint and one which would solve the failures of mechanical gasketed bonnet joints under elevated temperatures. The story behind the development of the Edward leak-proof Univalve* (sizes to 2½" in 1500, 2500 and 4500 lb. pressure classes) is the story of the product research that solved this industry problem.

EARLY EXPERIMENTING: Elimination of the bonnet joint entirely, by providing a one piece body-yoke construction, appeared to be a logical approach to the bonnet joint problem. But this created a new problem—how to apply and *how to service* an integral Stellited seat from a distant point at the top of the valve yoke. Some valve manufacturers chose to split the valve body near the seat and then reassemble the body with a full pressure weld. Others chose a full pressure weld at the normal bonnet joint position. Neither approach allowed the user to disassemble the valve and both approaches resulted in the sacrifice of a positive, permanent backseat—a desirable feature in any high-pressure valve. Edward engineers refused to make these concessions.

ENGINEERS FIND SOLUTION: After many attempts, Edward engineers developed a water-cooled welding torch for the application of the Stellite seat. This provided a stress-free Stellite layer of uniform density, firmly bonded to the body, free of cracks and pin hole porosity. Simultaneously, other Edward engineers sought the answer to the bonnet joint leakage problem. Extensive research and testing of a variety of body-bonnet combinations and seal-welding techniques resulted in the four elements of today's proven Univalve bonnet joint—a body-bonnet shoulder, load carrying thread, guiding section for alignment and the seal weld.

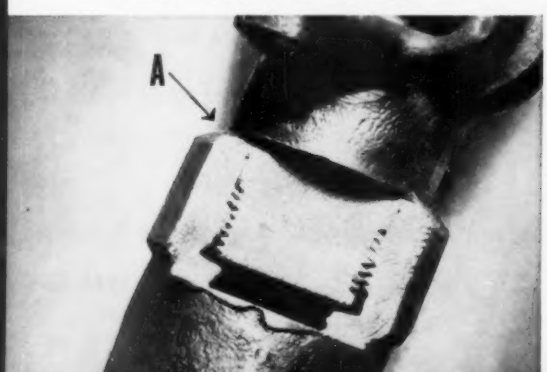
NEW DESIGN PROVES OUT: Months of research testing failed to find a weakness in the new design. Thousands of operations at rated pressure and temperature indicated long-time seat tightness superior to anything previously achieved. Bonnet joint design could not be made to fail at several times the valve rating. Tests were conducted with supercritical steam pressures up to 6000 psi at 1050 F in the only known facilities capable of producing those conditions at that time. And, to date, *hundreds of thousands of Univalves are in service with only one recorded instance of bonnet joint leakage*—a minor defect in the seal weld.

Edward builds a complete line of forged and cast steel valves from ⅛" to 18", in globe and angle stop, gate, non-return, check, blow-off, stop-check, relief, hydraulic, instrument, gage and special designs for pressures up to 10,000 lbs. For more detailed information, contact your Edward Representative, or write Edward Valves, Inc., 1206 West 145th Street, East Chicago, Indiana. Subsidiary of Rockwell Manufacturing Company. Represented in Canada by Lytle Engineering Specialties, Ltd., 438 St. Peter Street, Montreal.

EDWARD STEEL VALVES
another fine product by
ROCKWELL

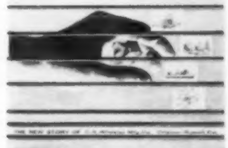
◀ **E. A. STICHA,** Chief Research Metallurgist, and R. K. Wagenblast, Research Engineer, measure temperature of valve seal weld in superheater test loop used in Univalve research.

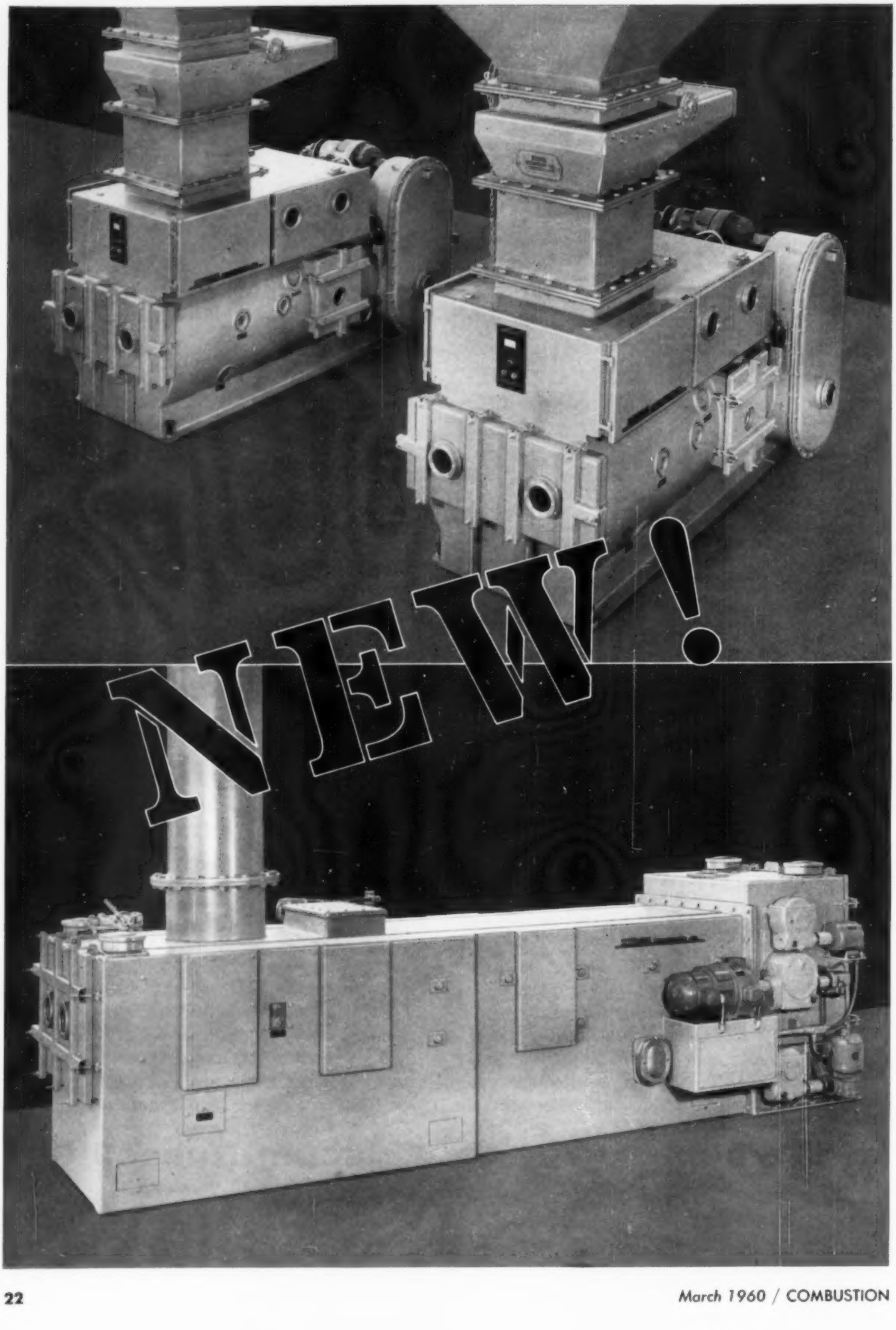
DESTRUCTION TESTS IN EDWARD LABORATORIES IN EARLY 1940's—Bonnet seal weld (A) of test valve cracked only after body creep occurred at 200° F above primary temperature and four times the primary pressure. ▼

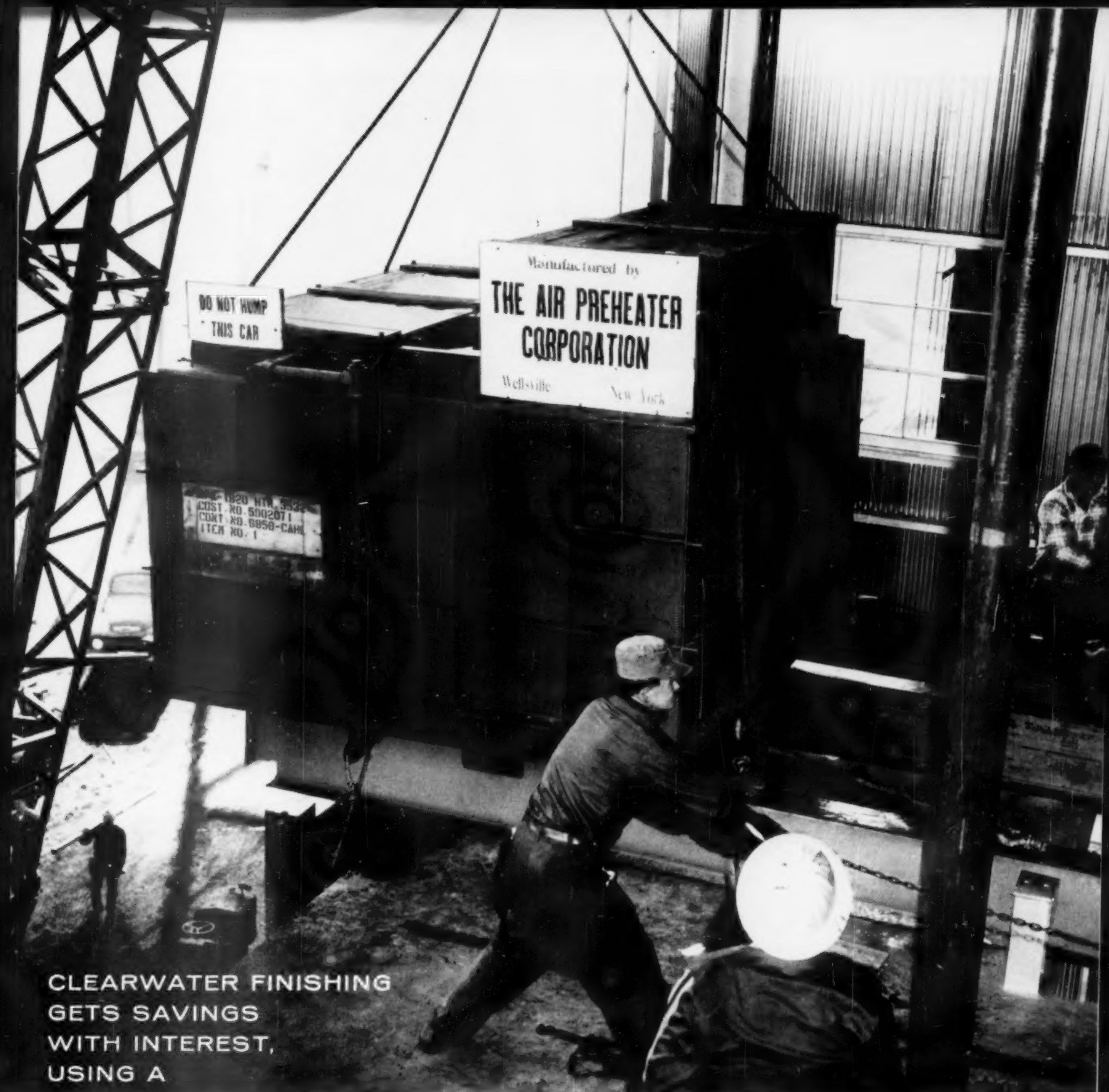


CRITICAL LEAKAGE PROBLEMS ATTACKED BY EDWARD RESEARCH ENGINEERS—(A) Bonnet leakage solved by design featuring threaded structural joint and seal weld; (B) Seat leakage solved by revolutionary Stellite seat welding technique.

*T.M. Reg. U.S. Pat. Off.




NEW!



PACKAGE AIR PREHEATER

Fuel savings alone pay for it in two years; installation costs cut by pre-assembly — —

Savings come in pairs at Clearwater Finishing Co., with the installation of their new Package Air Preheater. This is why:

1. Initial savings on installation. You can install a Package Air Preheater at a fraction of the expense required for conventional heat recovery equipment. The unit you see in the picture is a *complete* Package Air Preheater. To put it into service you simply lift it into place, make power and duct connections. It's that fast, that easy.

2. Long term fuel savings . . . $17,000 a year off your fuel bill (more or less, depending on size of preheater and application). What you save on fuel can pay for the Package Air Preheater within two years.

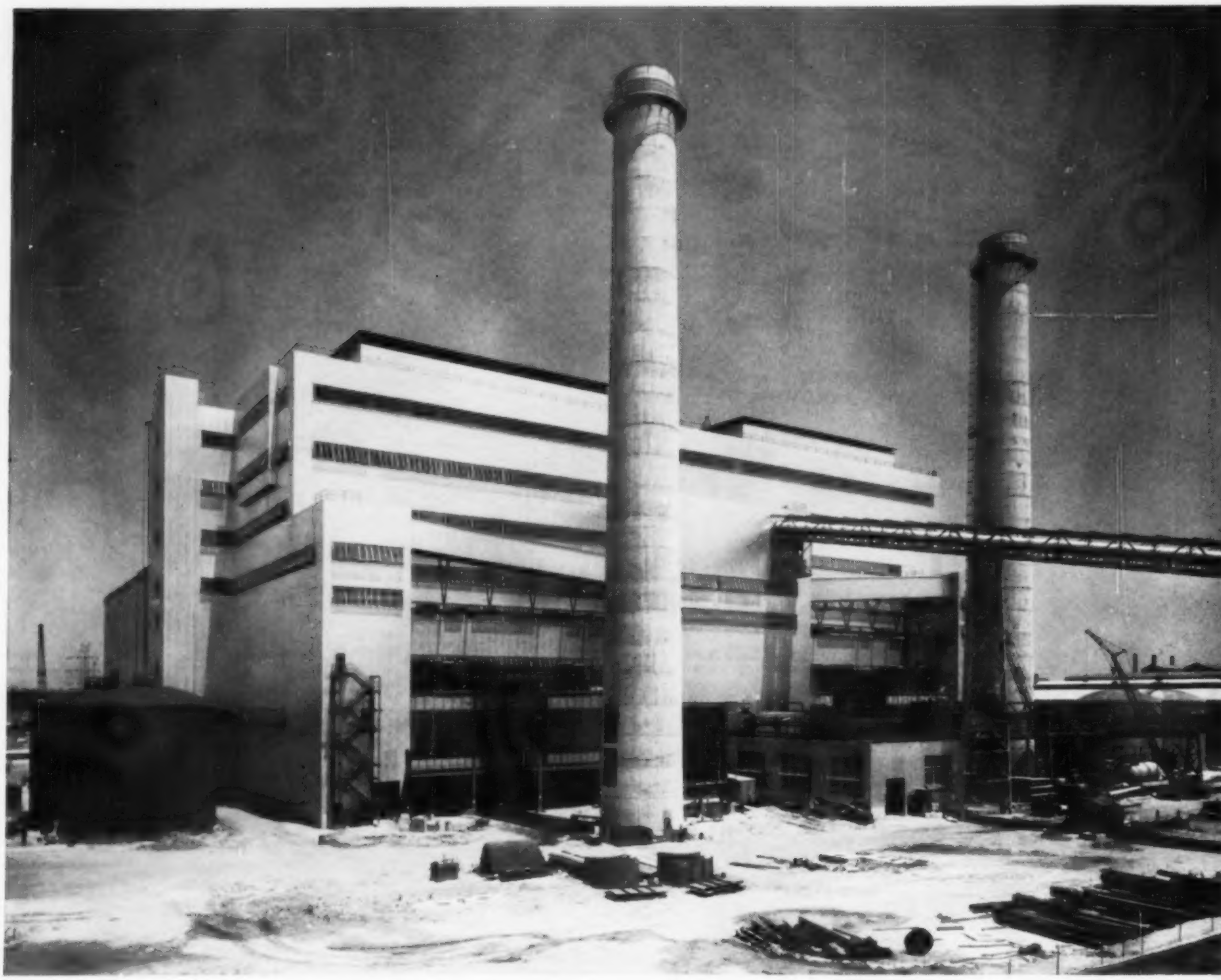
Installation savings are achieved through standardized design, which permits complete shop assembly. Fuel savings are achieved through the efficient continuous regenerative heat recovery principle, which cuts your fuel bill 1% for each 45-50°F increase in preheated air temperature.

For application ideas, and facts and figures on the potential savings, write for free 14-page booklet.

Completely pre-assembled Package Air Preheater is lifted into place at the new plant of Clearwater Finishing, (Division of United Merchants & Manufacturers, Inc.) at Clearwater, South Carolina. Installed at far less cost than a unit requiring on-site erection, this Package Air Preheater will serve a 83,000 lb/hr boiler. It measures approximately 8'x8'x6', and its 4900 sq ft of effective heating surface will recover 290°F from the stack gas.

THE AIR PREHEATER CORPORATION

60 East 42nd Street, New York 17, N. Y.
Phone: MUrray Hill 2-8250



Eddystone Station's Unit 1 has a capacity of 2,000,000 lb/hr at 5000 psig and 1200°/1050°/1C50°/F . . . uses C-E Sulzer Monotube Steam Generator.

Vulcan Selective-Sequence system provides Eddystone Station with precision soot blowing

When Unit 1 of Philadelphia Electric's Eddystone Station goes into operation, a Vulcan Selective-Sequence system will accurately control all soot blowing.

Selective-Sequence systems were chosen for both units 1 and 2 at this super-critical station because they assure positive, dependable boiler cleaning . . . make the most efficient use of the blowing medium.

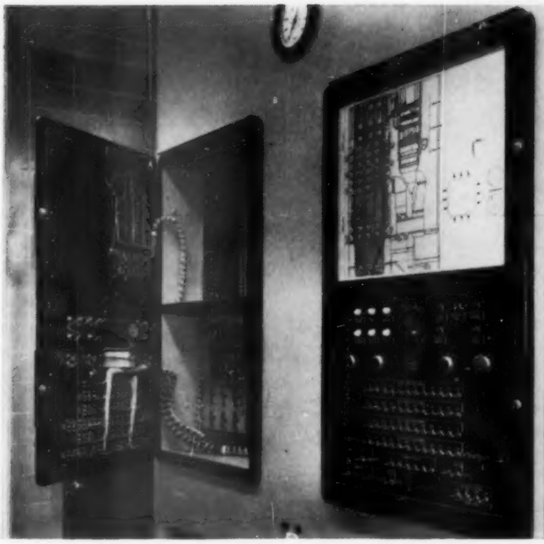
Vulcan Controller saves time. Without leaving the panel, the operator pushes a master button to place the system in sequential operation. He can see that each soot blower is operating in sequence for the proper interval with adequate pressure. He can modify the sequence to improve cleaning or conserve the blowing medium without time-consuming wiring and piping changes.

Vulcan long retractables speed cleaning. With dual-motor drive, Eddystone's T-30's minimize the danger of tube cutting or erosion. Low rotating speed increases range and penetration, decreases wear, eliminates whip, and permits cleaning with faster traversing speeds.

Half-'tracts with 19-foot travel, wall deslaggers, and air pre-heater controls are also used. For details, write Copes-Vulcan Division, Erie 4, Pa.

Copes-Vulcan Division

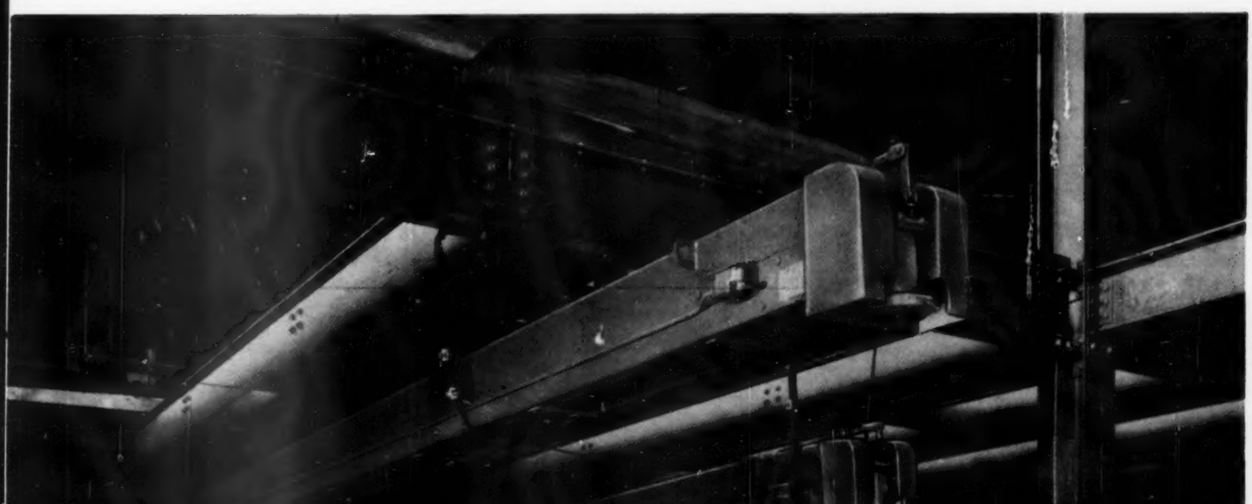
BLAW-KNOX

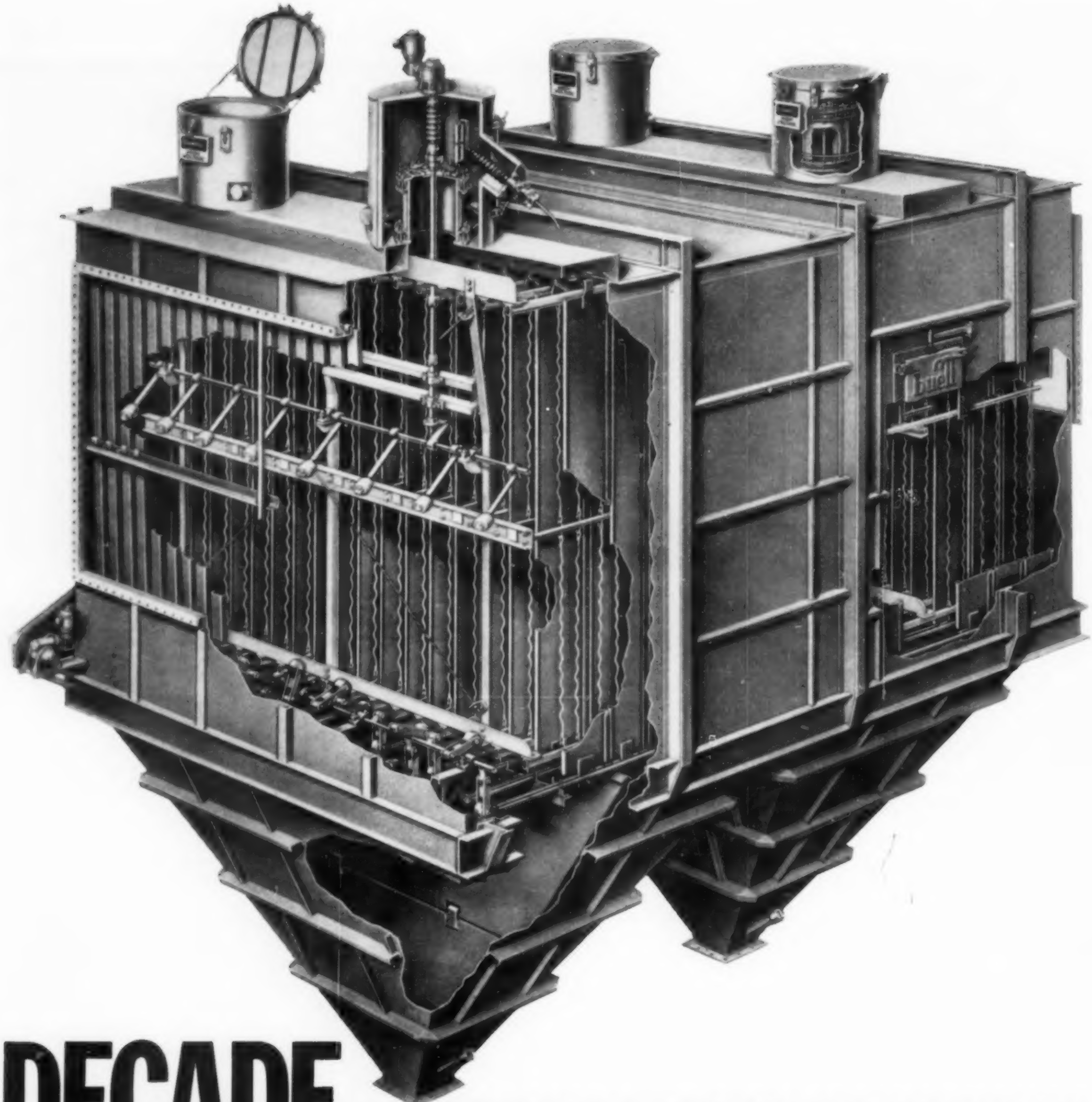


Panel provides centralized control of soot blowing at Eddystone. With the Vulcan SSC-120 Selective-Sequence controller, each blower can be operated four times during a schedule, or there can be four different schedules. The sequence can be varied by means of a jack board. Any soot blower can be operated at any point in the sequence by plugging one end of a patch cord into the blower jack, and the other end into the desired sequence jack. Write for Bulletin 1029.

Wall deslagger conserves steam generated at Eddystone by three special package boilers. High striking power of Vulcan RW-3E drives off gummy masses to assure high heat-transfer capacity, and uniform superheat and reheat temperature control. Dual motors are used: one speeds the nozzle to and from the blowing position, the other rotates it slowly for thorough cleaning. All parts are covered for protection, assuring long life with low maintenance. Write for Bulletin 1034.

Vulcan T-30's have 30- and 37-foot travels. Motors are mounted at the boiler end to facilitate maintenance, yet away from heat of the boiler wall. Their placement avoids interferences. Write for Bulletin 1030.





DECADE OF OPERATION PROVES MAINTENANCE OF BUELL 'SF' PRECIPITATORS AVERAGE LESS THAN 2%

In 10 years of selling 'SF' electric precipitators, the number of replacement parts ordered from Buell has amounted to only 1.17% of the total sales! Even on emitting electrodes, usually the most vulnerable part of a precipitator, replacement has amounted to less than 1% of the original number installed. What do these extremely low percentages mean? Exceptionally low maintenance costs, for one thing, continuous high-efficiency operation, fewer shutdowns and process interruptions. Buell self-tensioned emitting Spiralectrodes eliminate vibration found in weight-tensioned wires. Buell's low maintenance precipitators will provide you with the most satisfactory operating results. They're backed by 25 years of experience in dust collection, with the practical know-how gained on hundreds of installations. Write for descriptive literature. The Buell Engineering Company, Inc., Dept. 70-C, 123 William Street, New York 38, New York. (Subsidiary: Ambuco Limited, London, England). EXPERTS AT DELIVERING EXTRA EFFICIENCY IN DUST RECOVERY SYSTEMS.

buell®

Combustion
DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

EDITORIAL

Our Complex Industry

The average business man, and to some measure the engineer, counts among his strengths in holding his position an ability "to get on with it." In reviewing the forthcoming American Power Conference program we spotted one session labeled "Advanced Power Concepts" and thought immediately that the recent spate of publicity on these so-called newer energy concepts had prompted the program planners to feed the engineer's appetite "to get on with it."

We have no way of knowing at this early stage how this session will be conducted. We hope, though, that it uses an approach such as that employed by our British contemporary *Engineering* in its January 22, 1960 issue discussing magnetohydrodynamics (MHD). Let us quote:

"Physics research follows a modified form of Parkinson's Law: work expands to occupy available labor. Concentration of scientific effort on a problem leads to the production of a whole new set of problems. The number of elementary particles in atomic physics, for example, has increased in proportion to the number of workers studying them. More recently, the scientific effort amassed to attack the problem of thermonuclear fusion has produced as its chief result an awareness of the vastness and complexity of the problems to be found in magnetohydrodynamics (MHD for short).

MHD is the study of conducting fluids in magnetic fields. It is tempting to refer to it as a study of the fourth state of matter. But this could well be an earth-bound simplification. It happens that we are familiar with a world in which three states exist: solids, liquids and gases; but the greater part of the universe is made up of matter in quite a different state, whose complexity of behavior even suggests its classification into a new series of states. Inside and outside the thin crust of the earth, ionized matter, or plasma, interacts in a complicated way that has yet to be understood."

This article then discusses certain of these complications and while it does not go deeply into them it leaves the reader with a strong realization that the application of MHD to large scale power generation will take time. Even more importantly it serves notice on those of us with twenty and more years in the industry that we shall never master it. The industry is more complex than ever before and our plea in the editorial of February goes double. We need qualified youth in quantity.

Testing The Rotary Regenerative Air Preheater—Part I

By JOSEPH WAITKUS*

REVIEWING progress in design and operating practice over the last twenty years for central station and industrial steam generating plants, reveals the interesting fact that rotary regenerative air preheaters have been performing a function of ever increasing importance in an effort to achieve the ultimate in power plant operating efficiency and economy.

This is accounted for by increased recognition given to obtaining the highest possible recovery of waste heat in a continuous drive to attain the maximum overall operating economy in the face of rising fuel and labor costs. The trend is supported by a steadily increasing number of applications of this type of heat recovery equipment, stimulated by inherent advantages and by improvements in design and construction that assure good flexibility, reliability and availability.

Much has been written about the regenerative type air preheater from the standpoint of design and operation. These aspects appear to have been covered adequately in the record of current knowledge and practice. Only one aspect seems to have been neglected and that one is the important function of planning, instrumenting and conducting tests to determine performance with respect to heat recovery, resistance and leakage.

This paper's function therefore, is to present in useful form the accumulated experience of testing rotary regenerative air preheaters with special emphasis placed on a description of the apparatus and techniques employed. It should serve to clarify many details important to a satisfactory test, and offer reasons for deviating from certain generally accepted test procedures.

It might be well to first indicate the most significant features influencing the performance of a rotary regenerative air preheater, thus clearing the way for a better understanding of certain special requirements in the organization of a test program for this type of equipment.

Performance Characteristics

Fig. 1 illustrates the two principal arrangements of the rotary regenerative air preheater, usually referred to as a *vertical* or *horizontal* unit to indicate the direction of flow of air and flue gases. In Fig. 2, the equipment is is reduced to the simplest form to emphasize design and operating features. Note that the heat exchange matrix is in continuous rotation between the air and flue gas streams. Because of this feature, the regenerative principle of heat exchange cannot provide for complete separation of the two streams. Leakage takes place in two forms—as "entrained leakage," with the rotor carrying air into the flue gas stream and flue gases into the air stream; and, as "direct leakage" with air leaking into the flue gases, past sealing members fastened to the rotating element. It must be understood that the air is always under pressure while the flue gases may be under suction or pressure, depending on whether the boiler is designed for balanced draft or pressurized firing. In both cases, it is the pressure differential between air and flue gases that influences the leakage effect across sealing members in the air preheater.

Temperatures and flue gas composition are affected by the entrained and direct leakage so that the outlet air and outlet flue gases have a distinct gradient across the stream that must be considered in making temperature measurements and flue gas analyses.

Outlet temperature conditions are further affected by the change in temperature of the mass of heat absorbing surface or matrix as it moves across the air and flue gas stream. This may be easier to understand after noting Fig. 3, an actual recording of the metal temperature at several points in the depth of the matrix as it moves through both streams and across the wide separating partitions, referred to in Fig. 2, as "sector plates" between the streams.

Note the wide variation at the cold end, Couple No. 6, where the air enters and flue gases leave, and the com-

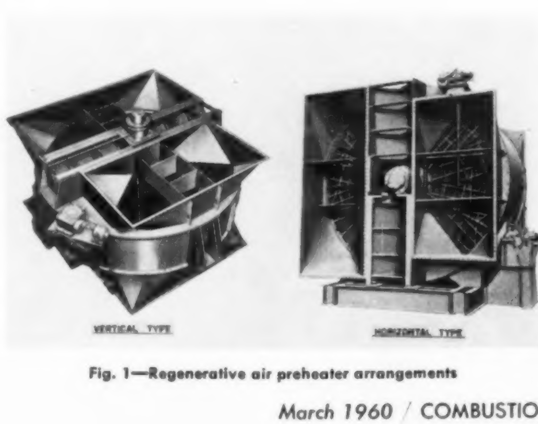


Fig. 1—Regenerative air preheater arrangements

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paratively small variation at the hot where the highest temperatures prevail with flue gases entering and hot air leaving. Note, too, the gradual change in metal temperature to a point of equilibrium and the length of the equilibrium period presumably a combination of the final period in the flow area—either air or flue gas as the case may be—plus the period over the sector plate between the air and flue gas flow areas. The variation in metal temperature follows changes in the load of the steam generating unit.

While rotor speed is usually kept constant at some selected figure between 1.25 and 3.5 rpm, it nevertheless must be pointed out that speed of rotation influences the performance of the equipment. A change in rotor speed effects the variation in metal temperature as well as the gradient condition with respect to outlet temperatures and flue gas composition. For example, reducing the rotor speed not only increases the variation in matrix temperature, but, in addition, modifies the composition and temperature gradient across the outlets of the equipment. With slow rotation, the matrix is cooled to a lower level on the air side and heated to a higher level on the gas side causing a wider variation in metal temperature. Furthermore, the rotor is purged of entrained leakage almost immediately upon entering the stream of air or flue gases. The effect of air dilution on flue gas composition and on outlet temperature gradients of flue gas and air are noted early. Increasing the speed causes the reverse action. It decreases the matrix temperature variation but it also drags the entrained leakage further across the duct area to create a distinctly different gradient in temperature and composition of the outlet streams.

A particularly noteworthy feature of the rotary regenerative air preheater is its compact arrangement. It serves to converge the flow into a dense moving matrix. By so doing, hot and cold spots in the heat exchange surface are avoided. All the heat exchange material assumes the same temperature at the same point in the flow area. Modifying the inlet distribution or conditions will, of course, alter the conditions in the matrix. A poor approach to the inlet of the air preheater can very well upset conditions within the matrix with subsequent deterioration of performance.

From the discussion above it should be apparent that the measurement of any performance factor in the regenerative type air preheater is complicated by inherent design and operating features. Particular attention will be devoted to certain procedures in order to obtain a reasonably accurate indication of the overall performance of the equipment.

The four principal factors to be measured in testing a rotary regnerative air preheater are shown in Table I.

TABLE I

Measurement	Location
Flue gas analysis	Flue gas inlet Flue gas outlet
Temperature	Flue gas inlet Flue gas outlet Air inlet Air outlet
Draft	Flue gas inlet Flue gas outlet
Air pressure	Air inlet Air outlet

Each of these will be discussed in detail, with emphasis on the equipment developed, the techniques employed

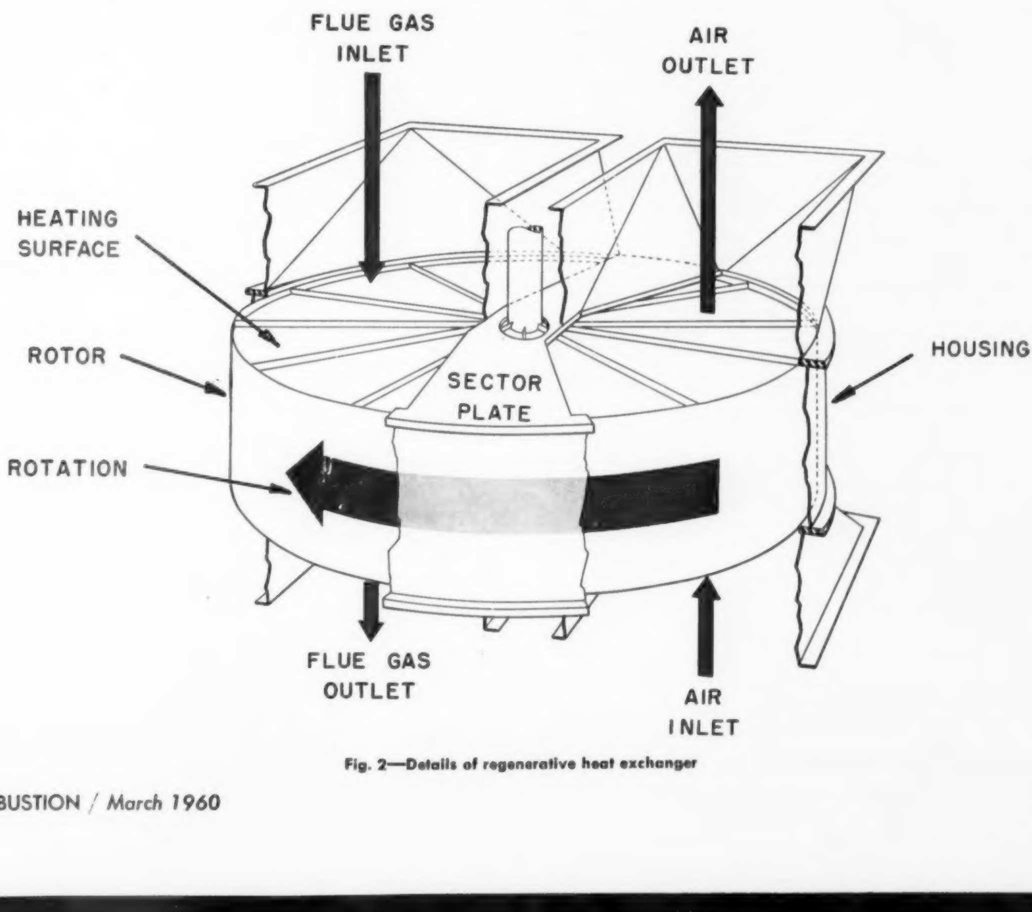

Fig. 2—Details of regenerative heat exchanger

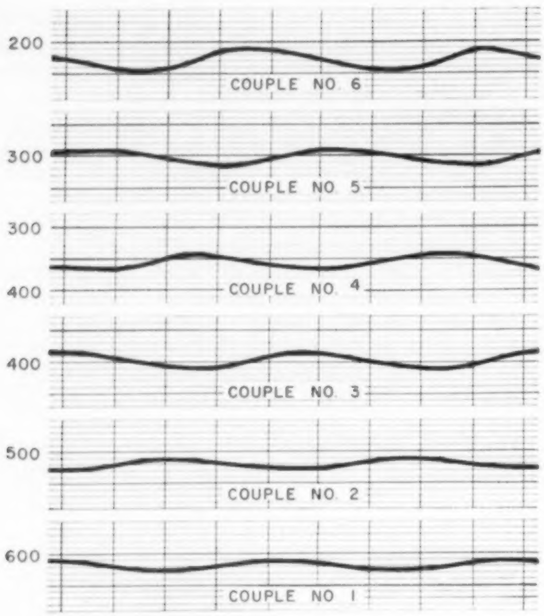

Fig. 3—Typical variation in metal temperature

and the important observations to make in preparing, organizing and conducting the test.

Flue Gas Analysis

Broadly speaking, flue gas analysis is the most difficult factor to determine accurately and reliably. This is critically significant because gas analysis is one of the most important measurements in evaluating the performance of the equipment. It might well be considered the key item in the test data and the calculations to follow. For this reason, no precaution is too great, no equipment too expensive, that will assure the accuracy and complete reliability of the measurements taken. The test personnel assigned to the gas analysis function will carry great responsibility. Indifference or carelessness in any respect can easily and quickly nullify the results of the best planned test program.

Attention has already been directed to the gradient conditions at the preheater outlets. The same complication may exist to some extent at the inlet of the equipment but usually it is not serious. If it is of any great magnitude, then it is reasonable to assume that the distribution and/or composition of flue gases across the boiler is not uniform or normal.

An inherent gradient condition across the boiler is a common condition and cannot be avoided. It is largely the result of air infiltration through the setting, casing and walls. For example, the CO_2 content at the inner face of the side walls is lower than at the middle of the boiler. This is a well established and accepted situation, varying with the condition of the boiler setting.

There is also the possibility that firing equipment may not be operating so as to uniformly distribute flue gases across the combustion chamber. The number of burners required to maintain satisfactory operation and economy are usually adjusted as the fuel and the load on the boiler varies. The arrangement of the operating burners influences the flue gas distribution and composition across the unit. Obstructions in the flue gas passages of the boiler, such as bypass dampers and baffles for various control purposes within the unit, can cause the same difficulty.

It is important to recognize that the flue gas distribution and composition within the boiler influences the distribution and composition at the preheater inlet. Too often this is ignored to the serious detriment of the final results of the test. In other words, one of the most fundamental conditions affecting the performance of the air preheater may not be receiving adequate consideration. This is a difficult point to judge because it depends so much on the arrangement of the boiler and air preheater—or preheaters, if more than one is applied. Fig. 4 illustrates this important point for two typical arrangements. If one air preheater, as shown in Scheme "B" is applied to the boiler unit, the arrangement of the flue gas passage may serve to intimately mix the flue gases and develop a reasonably uniform composition, resulting in a more or less uniform gas analysis across the width of the air preheater inlet. Turbulence is assumed to take care of the situation but while contributing to a more uniform mixture, turbulence may upset flow conditions and certainly affect the system resistance.

On the other hand, in the arrangement illustrated in Scheme "A," the width of the flue gas passage may not create sufficient turbulence to intimately mix the flue gases and stratification can develop. In this case, the flue gas composition may vary widely across the duct and would have to be explored with all considerations to obtaining enough measurements to assure reasonable average of the flue gas condition.

The examples in Fig. 4 are just two of a large number of possible or actual arrangements considered by plant designers. It would be entirely correct to state that there are as many arrangements available as installations made—no two are alike. Even in the case of duplicate units it should not be surprising to find the conditions different because of certain deviations or differences in operation between installations and units.

Any one or any combination of the items mentioned can affect the distribution of flue gases at the air preheater inlet. It prompts the suggestion that the inlet be traversed with the same care as outlet of the air preheater.

The gradient condition at the preheater outlet is of

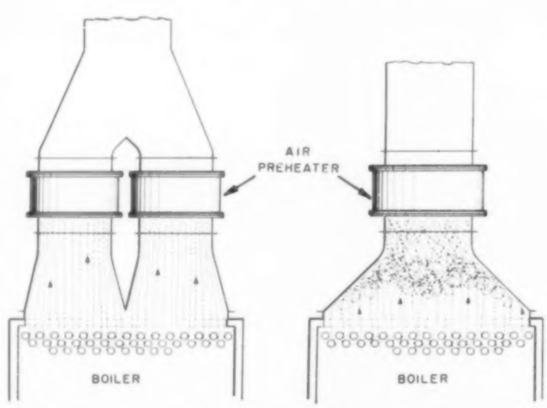

Fig. 4—Typical air preheater arrangements—flue gas inlet conditions Scheme "A" left scheme "B" right

course the widest in range, and accordingly requires the most precise attention because of its value in the final analysis of the results. There is no known way to eliminate the gradient, so it becomes a case of combining equipment, personnel and time in practical amounts to attain the best test results.

Equipment and Procedure for Gas Analysis

With this as an introduction to gas analysis, let us consider a few elements of equipment and procedure. The "orsat" is the universally accepted apparatus for the analysis of flue gases. A manually operated device, it requires more than ordinary care to operate and service. While it is admitted that anyone can learn to handle an orsat, it must be pointed out that the best operators are those who understand every peculiarity of the equipment they are manipulating. In other words, each operator must have complete familiarity with and feeling for, the equipment he is operating. By being so "tuned" to the orsat, he can quickly detect any abnormal behavior or results, and be in a position to take corrective measures with the least delay.

Sampling the flue gases is by far the most important part of the entire test procedure. With a gradient condition to consider, questions arise, such as—"Is there a method, or 'rule of thumb,' to follow in selecting the number of sampling points?"; or "How should the sampling points be distributed to give the best results?" It is to be kept in mind that the purpose of orderly sampling is to determine as closely as possible, the true average analysis in the area under test. Too little sampling can give an unrealistic average, and too much sampling may do nothing for the average but consume valuable time.

Attempts have been made to express precisely, by means of an equation or graphical representation, the minimum number of sampling points required for a particular test area. These attempts have been unsuccessful because they lacked consideration for numerous hidden and intangible conditions. Areas of the same dimensions need not necessarily have the same pattern and number of sampling points. The arrangement of the duct adjacent to the test area often influences the selection of the number of sampling points. Velocities and obstructions before and after the test area frequently determine the requirements.

With a significant factor so nebulous as to be practically impossible to define with reasonable precision, the test engineer faces a difficult problem. His decision may well determine the accuracy of the results and the subsequent success of the test. It requires careful judgment in planning the sampling point pattern and number with one purpose in mind, and that is to take a sufficient number of samples to assure an average result truly representative of the conditions in that area. The tendency should always be toward a greater rather than a lesser number of sampling points.

The suggestion has been made that pitot tube readings be taken to help determine the flow pattern, and from it establish the requirements for sampling. In most cases, it was found that the velocities were of such an unstable character, and the flow conditions so turbulent, as to make practically useless any measurements of this type.

As a guide in the preliminary phases of planning the sampling pattern, the following—based on duct area at the test plane—might be considered:

12 in. to 15 in. spacing for areas up to 20 sq ft
15 in. to 18 in. spacing for areas up to 60 sq ft
18 in. to 24 in. spacing for areas greater than 60 sq ft

A spacing greater than 24 in. between sampling points is not recommended. The spacing should be as near uniform in all directions as the dimensions of the duct permit within the limits recommended above. Avoid a single lane through the middle of the duct.

Speed is most important in sampling. Samples must be taken before conditions change too much at the several sampling points. Flue gases do not maintain a uniform composition at any particular point in the duct because of turbulence, inherent design features, and operating characteristics of the equipment adjacent to where the analysis is being conducted and at remote points as far back as the combustion zone.

Operating conditions of the steam generating unit—particularly the firing—may change rapidly and frequently. Such might be the case, for example, in a stoker-fired boiler where it is difficult to maintain stable firing conditions because of variations in the characteristics of the fuel, rate of fuel feed, and the quantity, temperature and pressure of the combustion air. Any one, or combination of these, may cause corresponding variations in the composition of the flue gases at a very irregular and rapid rate.

This situation is in marked contrast to the performance of pulverized coal, natural gas or oil-fired steam generating units. These fuels, with their respective methods of firing, result in appreciably less variation in flue gas composition. Nevertheless, viewing the matter in its broadest possibilities, it is important to consider any amount of variation as likely to substantially affect the accuracy of flue gas analysis. Means for rapid sampling are therefore highly desirable.

Simultaneous sampling at the inlet and outlet of the air preheater to assure comparable results is strongly recommended. It is a significant factor when the question of leakage is explored as a part of the air preheater performance.

Another consideration is the position of the sampling areas with respect to the inlet and outlet of the air preheater. It has been standard practice to provide covered openings through which sampling probes can be inserted. Unfortunately, ideal flow conditions are not always encountered at these points and it may be desirable to sample at other areas remote from the air preheater which may contain gases of a more uniform distribution composition.

Sampling position is more important at the outlet of the air preheater than at the inlet. It has been noted in many cases that the best average obtained at the immediate plane of the air preheater outlet did not compare favorably with the results, for example, at the induced draft fan outlet. The results at the fan may be found more useful as a measure of leakage than those close to the air preheater in spite of the influence of air infiltration into the flue gas duct at numerous points between the air preheater outlet and the fan. It is a case of recognizing the possible existence of stratification and taking measure-

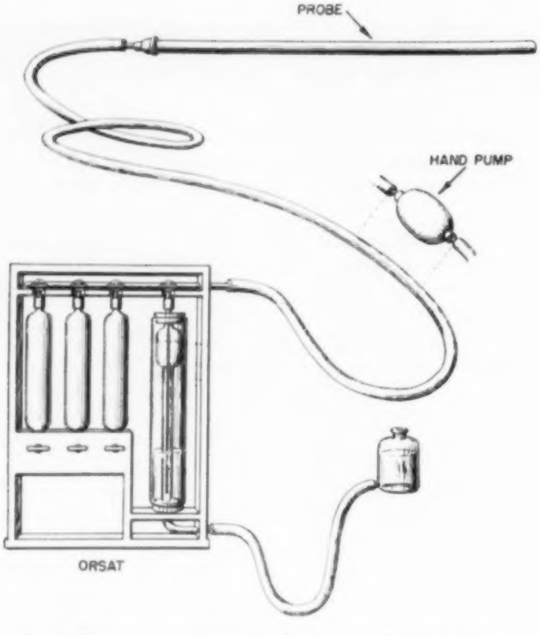

Fig. 5—Common arrangement for flue gas sampling and analysis

ments in a more uniform gas stream. It is therefore good practice to sample not only at the preheater outlet, but at the induced draft fan outlet as well, and, if conditions permit, at some intermediate point in the duct system where it is believed favorable gas flow conditions prevail.

The act of sampling flue gases requires a probe to explore the interior of the duct. An ordinary iron pipe of suitable size and length is usually found adequate for this purpose. The larger the pipe size, the longer the probe can be before it sags too much in the duct. However, a long probe is difficult to handle—particularly when it is hot and the job of manipulating it is conducted under difficult working conditions. Probing from both sides of a wide duct cuts probe length in half and requires less room for external handling.

It is desirable to provide not less than 1 in. standard pipe size nipples at least 4 in. long, welded in the duct wall at the points selected for test measurements. The nipple serves as a guide and support and can be capped when not in use.

Flue Gas Sampling

There are several methods for sampling—each having its particular advantages and disadvantage—some are simple, others are complex. All of the methods focus on the importance of obtaining a large number of samples in the shortest time.

Fig. 5 shows the simplest sampling method—a pipe probe inserted into the flue gas stream and connected by a rubber hose to an orsat. A hand pump or aspirator may be necessary depending on the suction in the duct system and the length of hose between the probe and instrument. A pump accelerates the movement of flue gases and the purging of the hose to the orsat. Samples are drawn from each point in the duct, and analyzed individually. The probe may be of a special design, as illustrated in Fig. 6, combining means for flue gas sampling with a thermocouple for temperature measurements. This refinement requires special design features to avoid contaminating the flue gas sample with air.

This method is simple; it can be set up quickly and at practically no expense, and it permits an unlimited number of samples across the duct. With several paths provided a very good average might be obtained under favorable conditions. Its disadvantages are more significant—it is so slow that the entire condition of the test area may change several times between the first and last sample analyzed. A fair average, under such conditions, cannot be obtained. There may not be enough time to conduct the test for several averages to reduce the error.

The next development is illustrated in Fig. 7. The sampling probe is equipped with a hand pump and a suitable collecting vessel, usually a rubber bladder from a football or basketball. The operation is quite simple, and is indicated in proper sequence. The probe is first inserted in the duct, and is purged by manipulating the

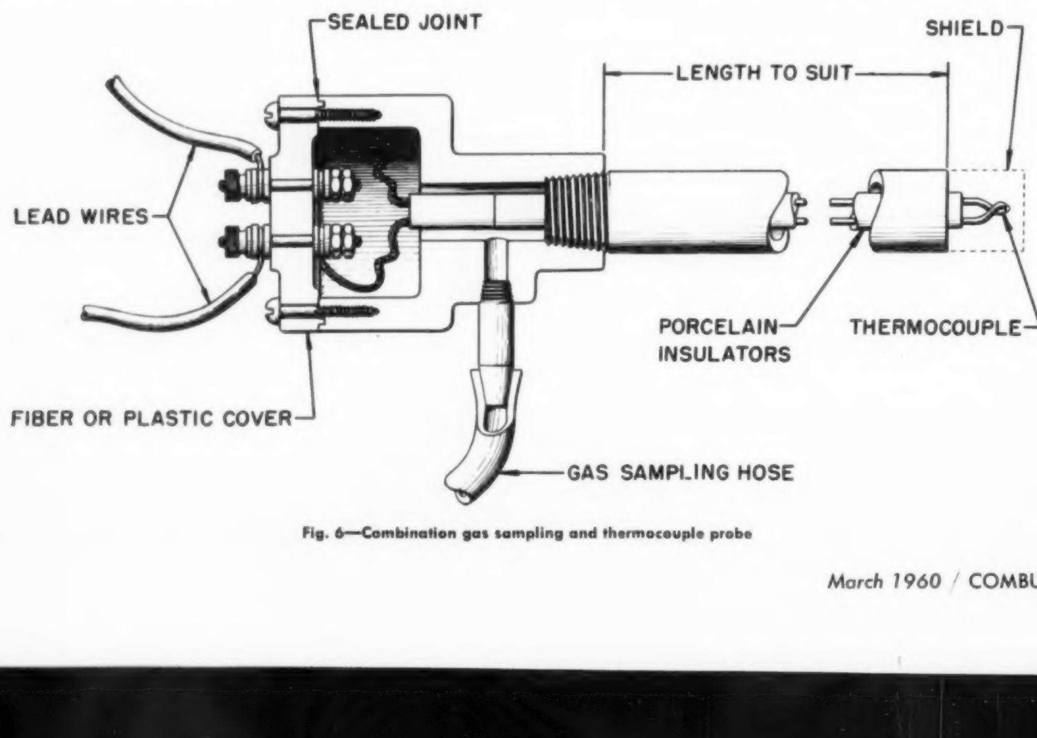

Fig. 6—Combination gas sampling and thermocouple probe

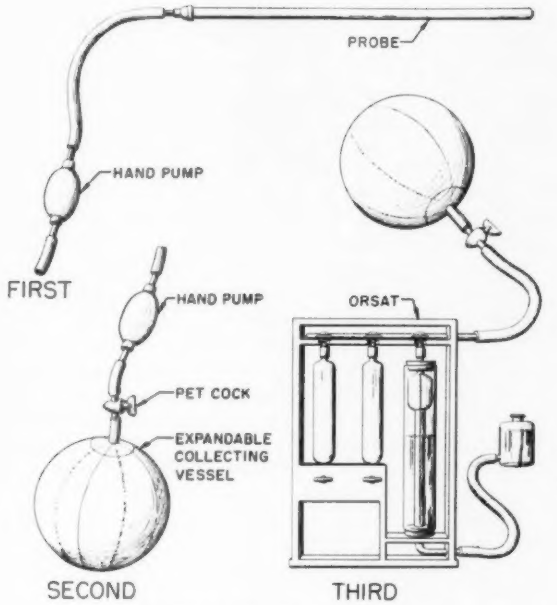

Fig. 7—Method for sampling flue gases

hand pump discharging the flue gases to the atmosphere. A generous pumping period is recommended to clear the probe of air and fill it with flue gases. If the hand pump is tight, it will prevent the suction of air into the probe under the negative pressure in the duct. Nevertheless, at the moment pumping ceases it will be wise to pinch the end of the rubber tube on the discharge end of the pump. This will prevent contamination of the flue gases with air.

The next step is to attach the hose to the petcock on the collecting vessel, making certain first that the vessel is reasonably empty of air. This is accomplished by rolling it into a tight mass before attaching it to the hose on the hand pump.

Having attached the collecting vessel, begin pumping flue gases. About ten to fifteen strokes of the pump per sampling point may be sufficient to obtain a generous sample. Obviously, as the probe draws samples from one point after another, they are mixed, forming a composite sample in the expandable collecting vessel. Attaching the inflated collecting vessel to the orsat permits analysis of samples under the most favorable conditions.

This method's advantages are noteworthy. It offers one of the simplest methods for obtaining a composite sample and the sample cannot be contaminated because the positive pressure in the vessel keeps air out. The quantity of the sample permits separate analyses by various test personnel with different instruments to get a cross-check on the results. The analyses can be made under the most favorable conditions with respect to location of the orsat, avoiding the uncomfortable ambient conditions that are endured when the orsat must be close to the probe.

The only significant disadvantage of this system is the improbability of drawing the same size sample from each point in the duct. This is of minor importance and is greatly outweighed by the advantages mentioned earlier since accuracy is not seriously affected.

One point to bear in mind in using this method of sampling is that rubber has an affinity for CO_2. It is recommended that a new rubber bladder be filled with flue gases and left inflated for about 24 hours. By that time the rubber will have become conditioned and will be ready for use as a collecting vessel.

The next refinement in sampling is illustrated in Fig. 8. It might well be referred to as the "bubbling bottle" method of gas collection. It consists of an inverted glass bottle equipped with several tubes, one of which is a suction tube. All the tubes, except the suction tube, are under water. The suction tube is connected to an aspirator which maintains a continuous suction on the bottle. With a negative pressure above the water in the bottle, flue gases bubble up through the water into the space above, and are continuously drawn away and discharged by the aspirator. The sample for analysis in the orsat is just ahead of the aspirator.

There are a few features to observe in the design of this

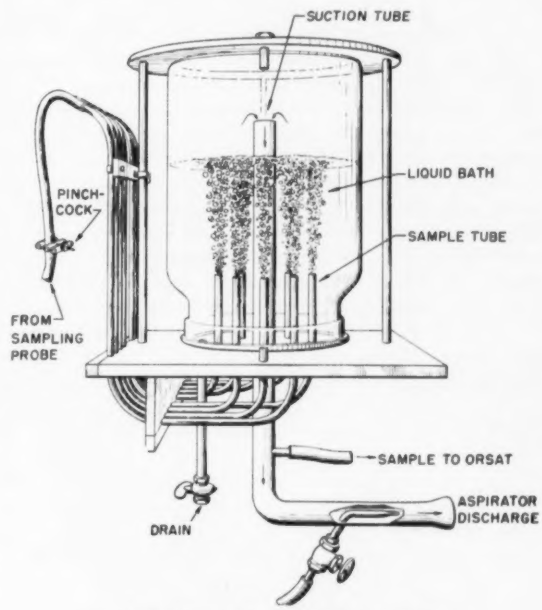

Fig. 8—Bubbling bottle method of gas sampling

type of flue gas sampler. The aspirator and suction system must be designed to handle a generous volume of gases from the full complement of sampling tubes provided in the bottle. There is the resistance to flue gas flow from the point of sampling, through the probe, connecting lines and water seal in the bottle, to be considered. The suction necessary to meet these requirements may be so great the sample may have to be pumped into the orsat.

An important part of this method of sampling is the means for valving or controlling the flow of flue gas so that an equal amount is drawn from each sampling point in the area under test. Pinch clamps are usually provided for this purpose. Adjusting the clamp and noting the rate of bubbling provides for reasonably uniform sampling.

This sampling method permits use of other types of probes, illustrated in Fig. 9. Type "A" is the simple

probe of Figs. 5 or 6, handled individually, or fastened together so they can be moved in unison, whichever fits the test plant best. Type "B" is an improvement, with concentric tubes each reaching a particular point in the dust area. This is an excellent type if not too many points are to be sampled—four appears to be the maximum. Beyond that number the size of the outer tube may require an undesirably large pipe nipple in the duct wall. It makes an excellent probe for sampling across the narrow dimension of the duct. Type "C" is another probe for sampling several points simultaneously. Here a number of tubes are fastened together to form a compact and rigid unit, excellent for distant probing. Each tube is open to a particular point in the duct area. With $^1/_4$ in. O.D. tubes, a great number of sampling points can be reached without the probe becoming too large in overall dimensions.

One point to bear in mind is not to use copper in any form exposed to the flue gas stream. Its reaction with acid substances in the flue gases causes a rapid wastage and deterioration of the material. It was found necessary to replace copper sampling probes before a test was completed. Thin-wall steel tubing—either common or stainless—assures a highly satisfactory probe.

The bubbling bottle method of sampling is a positive step in accelerating the analysis of flue gases with a good degree of accuracy of the composite sample. Acceleration is evident in the continuous extraction of a sample from several points in the duct simultaneously. Changes or variations in composition taking place at any point or points under test are certain to influence the composite sample, provided such changes are of sufficient magnitude. With the amount drawn from each point under reasonable control with pinch clamps, it appears certain that the composite sample represents very nearly the actual state of the flue gas stream at a particular instant. The analysis of composite samples can be as rapid as the operator can efficiently and accurately manipulate the orsat.

A significant feature of this method of sampling is in the means for isolating any point or group of points under test to explore their influence on the general composition of the flue gases. Tightening the clamp on the rubber hose shuts off the flue gas from that point and modifies the final composition of the sample from the remaining area accordingly.

A word of caution—be sure nothing interferes with a free discharge from the aspirator. Plugging the outlet places the bubbling bottle under pressure instead of suction, and may easily cause it to explode. It is recommended that the bottle be covered with a removable fine mesh wire screen of about #16 BWG to protect the test personnel, and that the aspirator be so designed that nothing can interrupt its free discharge.

Another development in gas sampling apparatus is illustrated in Fig. 10. It is the result of a desire to more accurately draw the same size sample from each point in the duct and thereby obtain a more representative composite sample for analysis. Refinements were made which created an approach to the ideal sampling procedure. However, as so often happens, the refinements introduced complications, (which will be noted later), and made the sampling operation a little uncertain as far as continuity is concerned.

The first refinement provided an orifice in each suction line. A removable disk with a $^1/_{16}$ in. orifice was assembled into a special unit, illustrated in detail "A" of Fig. 10, and applied to each line. Each orifice was calibrated to make certain all of them had somewhere near the same characteristics under like flow and pressure conditions. Assuming the orifices are all practically alike, and with manometers applied across each orifice, it was comparatively easy to adjust the manometers to a uniform reading by manipulating the pinch clamps. This offered the nearest approach to complete control of sample size from any point under test in the duct.

It was necessary to provide a filter in the suction line ahead of the orifice. The problem was to provide a leak-proof assembly, with easy access to the filter media for cleaning and replacement. The simple filter unit recommended is illustrated in detail "B" of Fig. 10. Fabricated from transparent plastic, it permits examination of the filter media without having to take it apart until necessary and contains only one screwed joint which can be made leak-proof by proper gasketing. Lamb's wool or glass wool are effective filter media. The packing should be loose in order to reduce the resistance to flow and still affect a good removal of most particulates entrained in the flue gases.

A further study of this sampling arrangement discloses additional interesting refinements. The individual flue gas samples are mixed in a common header from which they are drawn continuously by an aspirator. In this respect the arrangement is similar to the bubbling bottle method of sampling. On the way to the aspirator the composite sample passes three bleed-off connections. Two are connected to collecting bottles, and the third is intended for direct sample analysis. The collecting bottles are a unique feature, providing means for drawing a sample uniformly and continuously over a selected period of time. Control is obtained by the flow of water, under a constant head, between the stationary collecting bottle and a movable level-bottle carried on a coiled spring with special elastic properites.

The coiled spring stretches as the level-bottle fills with water. This lowers the level-bottle at the same rates as the level of the water drops in the collecting bottle. In other words, the distance between the water levels is practically constant, and in turn maintains a constant

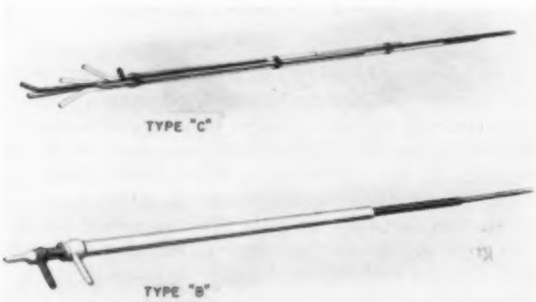

Fig. 9—Sampling probes

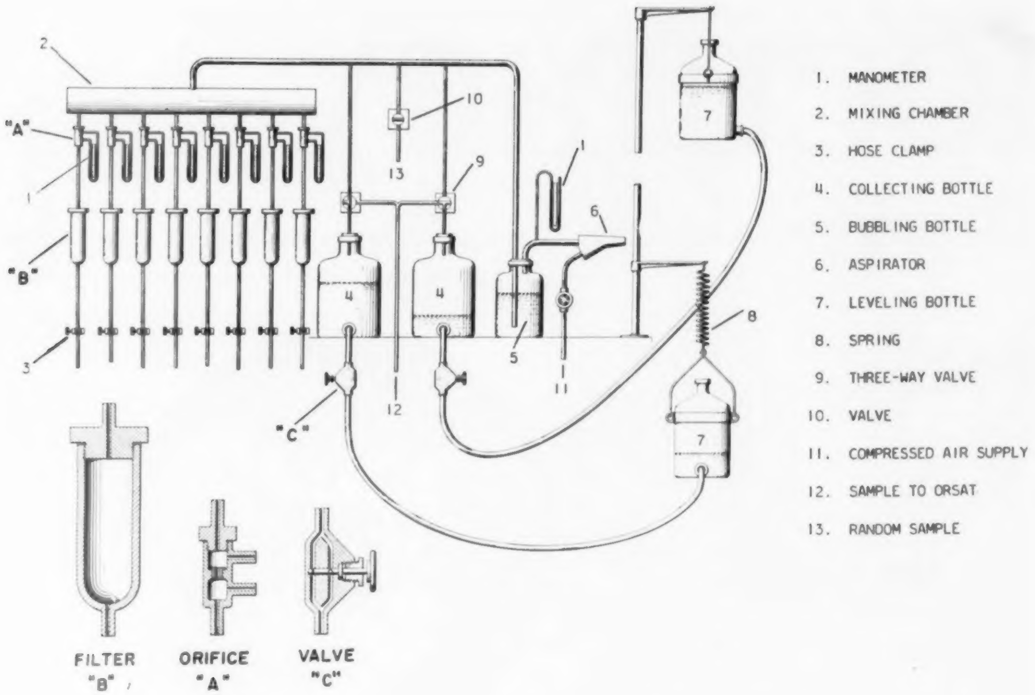

Fig. 10—Flue gas sampling apparatus with suction and collecting control features

head of water on the sampling line for composite gases.

A water orifice assembly, detail "C" in Fig. 10, inserted in the line between the collecting bottle and the level bottle controls the period over which the composite sample is drawn. Changing the orifice permits varying the sampling period as conditions of the test dictate.

Raising or lowering the level-bottle determines whether the sample is drawn into the collecting bottle or is forced out to the orsat. As the position of the level-bottle is adjusted, the two-way petcock is manipulated to direct the flue gases either into or out of the collecting bottle. Two collecting bottles are usually provided, one for analysis and one for the new sample.

When it is desired to analyze a composite sample, and the flow is reversed to discharge into the orsat, the water orifice may be bypassed by manipulating the knob, through 90 degrees, to present a larger orifice for flow. This permits a freer movement of water from the level-bottle into the collecting bottle, forcing the sample to the orsat.

The flow indicator bottle is a means for observing the rate of flue gas flow. The adjustment, of course, is at the aspirator where a valve controls the aspirating media. The manometer is useful for maintaining a constant suction on the gas sampling system.

There may be other methods for sampling flue gases, each developed around the reasoning and whims of the individual responsible for the test program. It is his interpretation of the problems and his imagination that develops different solutions. Each solution has some particular feature in its favor. None offer what might be considered an absolutely foolproof means of sampling since the human element is always an uncertain factor. Manipulation of each component of the apparatus plays an important part in the final result. Contamination of the sample by air infiltration or leakage is an ever present threat, making the simplest apparatus probably the least troublesome in this respect. On the other hand, the simpler the apparatus, the more time is consumed trying to obtain a truely representative sample. In the effort to meet this situation, the apparatus gets more complicated. The arrangement illustrated in Fig. 10 with a large number of joints, is susceptible to leakage in a very serious way. The development of new cements and joint sealing substances offer some insurance against leakage.

The need to obtain a true and accurate analysis of the flue gases is important enough so that investigators and researchers have actually transferred the techniques of the laboratory into the plant where the favorable laboratory atmosphere seldom exists. Dust, heat and vibration are just a few of the conditions working to the detriment of laboratory type equipment. It appears necessary to develop the practice of handling complicated apparatus under difficult and unstable conditions in the plant in order to obtain the results desired. This may be the only approach to a complete and satisfactory solution to the problem of obtaining a true analysis of the flue gases.

Next month we will publish the second and final part of this article describing modern temperature and pressure measurement techniques and equipment utilized in air preheater test work.

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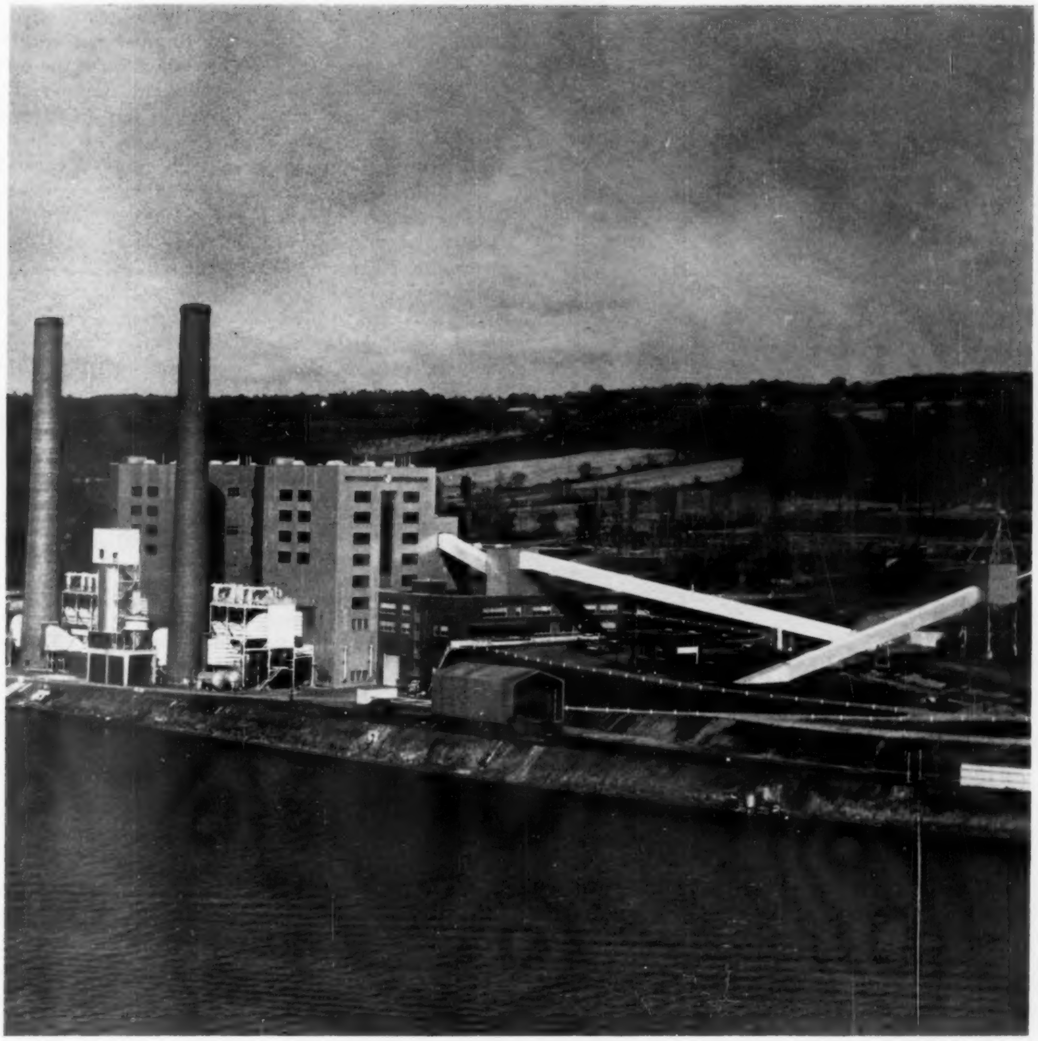


Fig. 1.—Miliken Station, New York State Electric and Gas Corp.

Dust Control at Milliken Station

By W. R. WISE*

In these days of heightened consciousness of civic responsibility on the part of power plant management this brief story of successful prevention of a neighborhood nuisance is particularly appropriate.

NORMAL considerations for the installation of dust control equipment on coal handling systems include reduction of fire hazard, cleanliness, improved working conditions and reduction of labor. An additional compelling reason at Milliken Station of the New York State Electric & Gas Corporation arises from the plant location on the east shore of Cayuga Lake north of Ithaca, New York. Being one of New York's Finger Lakes, it is a fine recreational area with cottages and beaches located so that air-borne dust from the unloading operation would present a serious nuisance.

* Plant Superintendent, Milliken Station.

Fig. 2.—Start of dumper rotation—first set of spray nozzles in operation

At this station, coal is received by rail on the plant siding and then transferred to the car dumper by the plant locomotive. From the dumper hopper, it passes through two coal crackers and two pan feeders to a 900 ton per hour stocking-out belt conveyor. The top end of the conveyor consists of a pivoted boom section which raises automatically as the height of the pile increases. At this point the coal is in live storage, or if an excess is received, it may be moved to dead storage by bulldozing.

The reclaiming system operates without attendance except for remote starting, stopping and feed rate setting by the control room operator. In reclaiming, coal is fed by four vibrating feeders to two double roll crushers and to two 300 ton per hour belts. A transportometer is installed on each belt to weigh the coal, and by means of a feed rate regulating mechanism, corrects the setting of the vibrating feeders to the desired value. The rate of feed is recorded in the control room, where bunker level indicators are also installed. The system shuts down automatically on a full bunker.

Because of the many operations and transfer points in this system, and the high prevailing winds in this exposed location, dust control demanded close and special attention. Because of its inherent advantages, the use of a spray system with a wetting agent was indicated. Dust would be controlled at its source, and the wetting and penetrating characteristics of the solution would tend to make the coal dustless throughout the handling cycle.

The wetting system was designed to treat 900 tons of coal per hour on the stocking-out system and to operate at a variable rate on the reclaim system as the rate of coal feed varied. The car dumper unloads a coal car in 40 seconds by rotating through 160 degrees. For this operation, a proportioner system for spraying 165 gallons per hour of solution is provided. Here the wetting agent is pumped to a turbulence chamber for mixing with house service water.

A bank of spray nozzles on the dumper is arranged to spray the coal as it empties from the car during its rotation. Two additional banks of spray nozzles are mounted on the front and rear of the hopper to effectively blanket that area. When the dumper has rotated 18 degrees, it actuates the switches which open the solenoid valves to the bank of nozzles on the dumper. At 37 degrees, the valves supplying the headers on the hoppers are opened to control any dust emission from that area. At 150 degrees, the supply to the dumper sprays closes, and at 160 degrees, the valves to the hoppers close.

At the point of discharge from the pan feeders to the stocking out belt, additional nozzle headers were installed to provide treatment for the transfer point and to control dust throughout the conveyor enclosure. The lasting qualities of the solution are most apparent as coal discharges from the end of the boom where there is ample opportunity for fine particles to become air-borne. Savings in windage losses are difficult to estimate, but are nevertheless quite important.

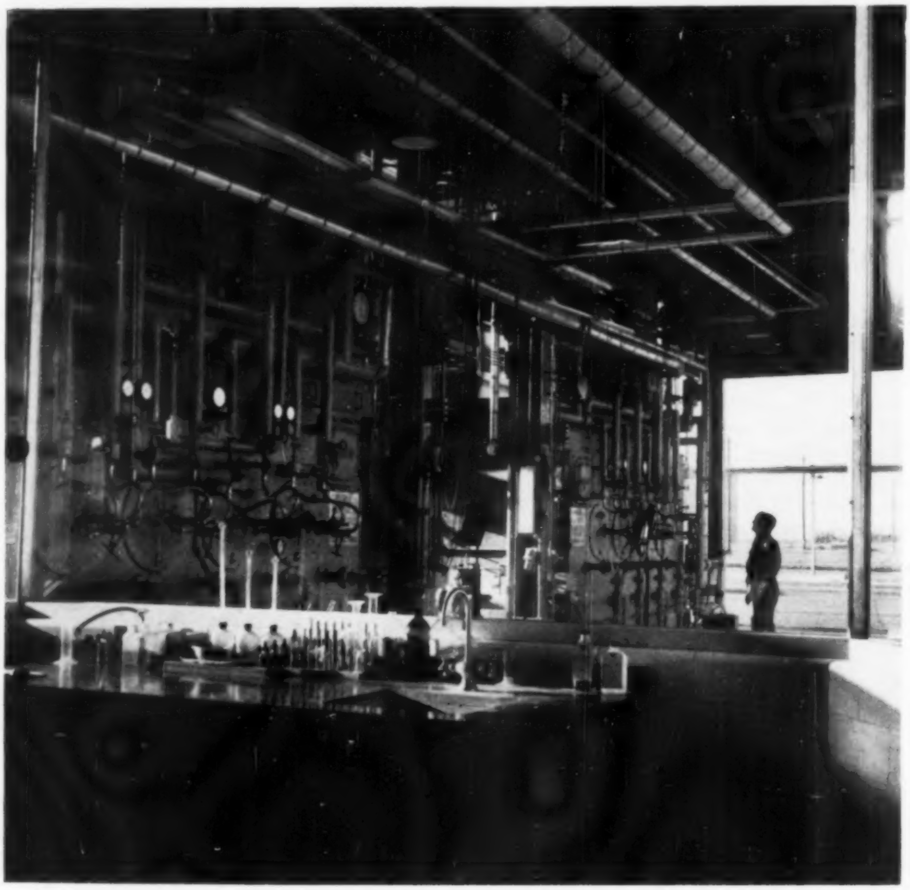
In the reclaim system, coal is wetted at the discharge of each vibrating feeder and in each of the discharge chutes from the crushers to the belt conveyors. At each wetting point there are three sets of spray nozzles which are operated at varying rates of coal flow. On each transportometer are mounted three rate switches which actuate the solenoid valves to the proper set of nozzles. The first group will spray at 40 tons per hour or greater, which represents the minimum flow rate. The second set operates at 120 tons per hour or more and the third set at 250 tons. Since these conveyors operate without attendance at most times, the advantage of dust control is most beneficial to the station in that cleaning and fire hazards are reduced to a minimum. The installed capacity of the coal handling system is considered large enough for the ultimate station capacity and no additional dust control equipment will be required as future generating units are added.

The widely varying types of coal and climatic conditions have proved these controls to be sufficiently flexible to satisfy the demands of the operating personnel and to avoid any complaints from adjacent homes and cottages. Maintenance and service requirements are nominal and reliability has been excellent.

Fig. 3—Car rotated 90 degrees—all nozzles operating

Economics of Plant Operation and Equipment Replacement*

By G. E. ANDERSON†



View of firing aisle from control room at Procter and Gamble plant, Sacramento, Cal.

Dollars are always of vital concern to all of us but in power plant operation the elusive dollar must always be kept in proper perspective. For our industrial readers we present here the principles used by one organization to keep its power service dollars harnessed and working efficiently.

ON THE subject of economic operation, some of us may be fortunate enough to have one of the new economically designed plants. This gives a head start towards making the Operating Ledger sheet look good. Others find it necessary to struggle along with the old plant that has been around for a while, but in either case there are some basic maxims which hold true for economic operation.

The old problem of not being able "to see the forest for the trees," applies all too frequently in the operation of some of our power plants. It is too easy to become

* Presented during the Special Lecture Series on Power, Cincinnati Section, ASME.

† Section Head—Heat and Power Dept., Engineering Div., Procter & Gamble Co.

overly absorbed in immediate short term economy considerations to the extent that we do not keep some important overall economic factors in proper perspective.

These are some areas to keep in focus for any *forestral* approach to power plant economics.

1. Safety.
2. Reliability.
3. Equipment life.
4. Civic responsibilities.
5. Day to day costs.

Safety

Safety plays a dominant part in any economic considerations involving operation or replacement.

We are dealing with potentially hazardous pressure vessels, expandable fluids, explosive combustibles, high speed rotating equipment, electricity and the like which require our respect and vigilance. There is *no economy* if they get out of hand in a serious failure which wrecks our plant, or which causes people, sometimes innocent bystanders, to be injured or killed.

Economical operation must strive for safety first and foremost. Our only economical approach where safety is involved is to:

1. Be as sure as we can that our plant is safe through proper and qualified design and inspection.
2. Maintain it safely.
3. Operate it safely.
4. Shut it down if there is a question that it is not safe.
5. Replace it if it cannot be economically repaired.

Chance taking and mishaps fostered by the pressures of production, inadequate training and short sighted economies present a serious safety problem today. My company was concerned sufficiently to expend nearly an entire day on the subject in a recent assembly of our various plant engineers. Such practices and responsibilities as these were re-emphasized:

1. *The need for proper training and information.* We must know the "hows" and the "whys." Training needs to be continuous, particularly if there are fluctuating personnel.

2. *Use safe maintenance operating practices.* (Such as are prescribed by the ASME Boiler Codes; by the ASME Rules for Maintaining and Operating Boilers; by Manufacturers, by Insurance Companies and by our own experience and good sense.)

3. *Inspect regularly and thoroughly.* Knowledge of the condition of our respective plants is primarily the responsibility of owners and operators. But don't hesitate to seek qualified help from engineers, manufacturers, insurance companies and water treatment specialists when they are needed.

4. *Maintain and test regularly* the safety devices and instruments which guide our operations. Failure of safety devices through neglect, tampering and bypassing is a growing problem as more reliance is being assigned to such devices on power plant equipment. Frequently this trend spells a need for upgrading technical skill for maintenance.

5. *Keep management informed and secure their backing for safe operation.* Be ready to raise the warning flag against the pressures of production when safety is at stake.

Reliability

This is a most important aspect for *economic operation.* The power plant is the heart of the factory. If the steam and power fails, the mill ceases to produce.

Day to day power plant operating economies may become relatively insignificant as compared to the costs entailed by unreliable operation. In Proctor & Gamble we have boilers and turbo generators whose outages may result in losses of thousands and tens of thousands of dollars per day. Yet we must continue to educate and remind ourselves, and our management, of the importance of maintaining reliability in proper focus in relation to day-to-day economy pressures.

We work hard to attain reliability in P&G. This is our record for our boiler houses over the past five years. (For boilers ranging in age from 1 to 50 years.)

For both scheduled and unscheduled outages, the boiler availability was..	96.9 per cent
Availability, exclusive of scheduled outages was........................	99.7 per cent

Some of our boiler houses have been operating for the past 5 to 9 years without a single emergency outage.

We are not satisfied and are continually trying to improve.

Reliability with carefully planned and scheduled outages frequently permits sound decisions to eliminate or reduce standby equipment requirements. Such policy decisions in my company have led to utilization of existing standby to support plant expansions, and minimized standby in new installations. Very large capital expenditures have thereby been saved.

Safe operation contributes greatly to reliable operation. But if reliability is an objective, we must also look to such areas as preventive maintenance for coal and ash handling equipment and the like, where safety is not necessarily involved. Details like the soundness of the $^3/_4$ in. drum vent become important.

Equipment Life

Equipment life is influenced from inception by the quality and type of its design and construction. Its life is also materially influenced by the way we inspect, maintain and operate it. Prolonged life is usually another by-product of high safety and reliability standards.

Boiler life spans can be materially shorted by malpractices such as:

1. Serious overloading.
2. Improper boiler water conditions.
3. Improper layup during idle periods.
4. Bad welding (which may set up undue stresses leading to subsequent failures).
5. Condensate and water leaks and drips which result in external corrosion to pressure parts.
6. Baffle failures which result in local overheating of pressure parts.
7. Weaknesses, which if discovered and corrected early are repairable—but which if neglected, progress beyond safe repair.

Long range power plant operating economy (looking at the forest instead of the trees) cannot neglect factors

which influence reasonable and long life. They merit proper perspective and balance against the pressures of short term economies.

Some insurance companies speak of an arbitrary 30 year life expectancy for boilers. P&G has had many boilers which have fallen far short of this age. We have many others going strong at 30 to 50 years with no end in sight. We soon expect to have many more in this age bracket.

Deferred capital expenditures for their replacement are tremendous for uses that serve our company to better advantage.

Civic Responsibilities

School heating plants or power plants for public buildings have compounded safety responsibilities beyond those already mentioned.

We need to support fair air pollution laws.

Responsibility does not stop with just the installation of fly ash collectors and overfire jets. Money and time are also required to maintain them.

Most of our "hard boiled" but progressive managers recognize that it is just plain good business to spend within reason to maintain good public relations. Here we can gain extra personal satisfaction by our participation in the effort to secure a better community for ourselves and neighbors.

Day In and Day Out Operating Economies

Important dollar saving opportunities are seemingly endless while still maintaining their proper perspective with safety, reliability, equipment life and civic responsibilities.

These are some potential operating losses or savings applicable in some of our plants where normal load is about 125 to 175M#/hr with coal at about $6.50 to $10.00/ton.

1.	1 per cent Boiler efficiency is worth about	$4,000/yr.
2.	A 1 per cent variation in carbon losses to the ash pits represents	$4,500/yr.
3.	A 1 per cent increase in blowdown beyond that needed for good boiler water at one plant means	$5,000/yr.
4.	If turbine driven feed pump is operating when exhaust might go to atmosphere, save by using alternate motor driven pump	$6/hr.
	Conversely, if exhaust from turbine can be absorbed by factory, save by turbine over motor	$2/hr.
5.	Extra cost at another plant to leave hand valves open on turbines during periods when not needed	$2,500/yr.
6.	If flue gas temperature increases 25 deg. F because of fouled surfaces	$3,000/yr.

Day to day potentials encompass fuel selection (which I believe is to be the worthy subject of another meeting) planned maintenance, personnel considerations and many others.

Practical ways and means that can be found to improve the efficiency of the steam and power usage in the mill often produce excellent savings for our time and effort. Opportunities range from simple plugging of trap and pipe line leakage and maintenance of insulation to the addition of heat reclamation systems. I know of many instances where time was well spent in this area. One in particular applied to a fully loaded boiler plant which was to be expanded to meet a 30 per cent production increase.

Steam load scheduling, the plugging or reduction of sewer and atmospheric heat losses, the application of some insulation and the installation of some simple heat reclamation devices were combined to eliminate the need for the new boiler. The result was a substantial investment saving and an attractive day to day steam saving.

Justification of Equipment Replacement

Now in considering the justification of equipment replacement let us revert to four of our basic points:

1. Safety.
2. Reliability.
3. Equipment life (or age).
4. Day to day savings.

To these, we must add a very important fifth consideration called Capital (or Investment) Cost.

Safety has been the dominating reason for replacements in my company. We have condemned 126 major boilers, turbines and engines during the past 30 years. 91 resulted in permanent retirement and replacement. 35 were restored by major repairs.

The need for *reliability*, coupled with other economic factors has played its primary role in decisions to replace and to augment our facilities. Power plant replacements cannot be justified because of age alone. This is a hard conclusion after dozens of special inspections and information exchange with others. We have condemned some units after several years. We have others going strong with no predictable end in sight strictly because of age. But I hasten to add that age bears respect. As equipment grows older, we firmly believe that its continued use must justify the cost of periodic comprehensive inspections by highly qualified inspectors and engineers looking for signs of fatigue, hidden corrosion, embrittlement, metal deterioration and the like.

All of our boilers, as they reach 25 to 40 years (dependent upon certain design features) are subjected to a rigid tear down inspection. All pressure parts are fully exposed. Internal surfaces are acid washed. External surfaces are sandblasted. Magnaflux and other nondestructive tests are applied. Metal thicknesses are checked by drilling and audiogages. Trepan samples are metallurgically checked. Some rivets, straps, or a blow off pad may be removed to look for embrittlement or stress cracking. Areas vulnerable to fatigue and quench cracking are checked and re-checked. If the boiler survives this check, and dozens of ours have, the

ADDENDUM

Readers interested in "Space Age Hydrostatic Test" by R. A. Nickerson in our January 1960 issue should add "partially fill reheater line to provide seal on stop check valves" to step 4 under "Procedure for Hydro to Reheater." Leakage past the checks can give the appearance of a bad leak.

boiler is then rescheduled for another such check in another 10 to 20 years. The special inspections in no way eliminate the need for continued vigilance during the regularly scheduled inspections and the reopening of some special inspection if suspicious conditions come to light.

Thus we repeat, expert knowledge of a particular equipment's potential safe life is a most important justification consideration for replacements. We do not believe that age alone is an all important criterion.

The importance of *day to day savings* which can be accomplished by more efficient, modernized replacements are well recognized. They have played their strong role in helping to justify replacements which we have made. They will continue to do so. But it is a hard fact that it is difficult today to justify an *industrial* power plant replacement strictly for potential day to day savings. Often times some replacements may be justified when coupled with plant expansions where they then need only justify the incremental costs of larger new equipment.

Improvements for day to day savings have often exhibited more attractive *investment returns* for us than complete replacements. Some such improvements which we have recently adopted are:

1. Conversions to alternate fuels.
2. Centralization of controls and operations.
3. More automation and instrumentation.
4. Add small automatic boilers for some remote week end and night time operations to permit shutdown of large units.
5. Heat reclamation facilities to improve efficiencies.

High initial installation costs are a dominant factor in making it difficult to replace through savings. Equipment manufacturers are recognizing this and are working to help reduce these costs by such devices as more standardization, and more shop assembly. Our consulting friends are looking more and more to building savings and simple rugged designs.

Then there is the tax angle. The corporation income tax has been most important in making it difficult to achieve acceptable pay back by replacement savings. Often times, 40 to 50% of any gross savings evolving from an improvement goes to Uncle Sam leaving only about 50 to 60% of these savings to apply towards payback of the investment. Most every industry has its own particular justification formula approach. I am certain that all must include this tax angle in some form. I believe that, all things considered, the tax structure is a more dominant factor in most industrial financing than it is in utility financing.

Heat & power usually continue to be needed in an industrial plant to support its production irrespective of changes in process. Thus it may often be right to promote longer payouts for basic power plant replacements. But to facilitate replacements for economies, it will pay to continue efforts for lower capital costs without sacrifice of safety and reliability.

Imagination, alertness, research and development for new things is needed at all times to help this economic picture.

It is important to keep the forest and the trees in proper perspective in our day to day operations and decisions.

This means that in connection with our day to day Economics, we must also pay due regard to: safety, reliability, equipment life and civic responsibilities.

Justification for equipment replacement, at least in our experience, will most often be brought about for safety and reliability with a big assist from day to day savings.

To accelerate replacements via savings, we need:

1. Reduced equipment and construction costs without sacrifice of safety and reliability.
2. Some corporation tax relief.
3. Imagination, new thinking and action for savings by other means than those considered conventional today.

Meetings Schedule

National Association of Corrosion Engineers—16th Annual Conference and 1960 Corrosion Show, Memorial Auditorium, Dallas, March 14–18

American Power Conference—22nd Annual Meeting, Sherman Hotel, Chicago, March 29, 30, 31

Pacific Coast Electrical Association—Engineers & Operating Meeting, Hotel Claremont, Berkeley, Calif., March 31–April 1

Maryland Utilities Association—Spring Business Meeting, Lord Baltimore Hotel, Baltimore, April 1

Sixth Nuclear Congress—New York Coliseum, New York City, April 3–8

Southeastern Electric Exchange—Engineering and Operation Section, Roosevelt Hotel, New Orleans, La., April 7–8

American Institute of Electrical Engineers—Southwest District Meeting, Houston, April 4–6; East Central District Meeting, Charleston, W. Va., April 12–14; Paper and Pulp Meeting, University of Florida, Tallahassee, April 21–22; Great Lakes District Meeting, Milwaukee, April 27–30.

Third Annual Conference on Automatic Techniques, sponsored by ASME, IRE, AIEE, Cleveland-Sheraton Hotel, Cleveland, April 18–19

American Society of Lubrication Engineers, Annual Meeting and Exhibition, Netherland-Hilton Hotel, Cincinnati, April 19–21

Feeling the need for free and open discussion of some of the major power problems currently facing industry, *Combustion Engineering Inc.* recently arranged for the first in a series of Industrial Power Forums. This initial Forum was held at Atlantic City during the Annual Meeting of the ASME and was spotlighted by a meeting on the previous day featuring papers* on this subject by two authorities who subsequently sat as panel members for our Forum.

The Combustion Engineering Industrial Power

In advance of the session all panel members were advised that the objectives were new ideas, untrammeled personal opinions—with the clear understanding that no comment by any individual would be construed as representing his company's policy and that no comment would be associated with an individual's name if he had any objection.

Energize or De-enerize to Trip?

Since interest in the papers of Messrs. M. L. Jones and J. B. Smith** at the previous day's ASME session on Boiler Safeguards had been so intense the discussion was opened with a question remaining unanswered from the day before—"Should not safety shut-off valves which must be energized to trip (close) be considered in cases where power failure occurs frequently?"*

A. W. Hindenlang . . . "Let's start this off with a show of feeling on the proper way to trip out a burner. Should you energize to trip, for example, or de-energize?"

M. L. Jones . . . "De-energize, of course. We've found you can't rely on interlocks or combustion safeguards which a short circuit can incapacitate. You use your energy source to open."

Arthur Dunn . . . "Just the opposite in certain aspects. We prefer to 'energize-to-trip' pairs of burners when this action is necessary. In four years we have not encountered a single failure of a tripping device coil. This is due, no doubt, to the fact that the 'energize-to-trip' circuit is a pulse type and the operating coils are energized only during the pulse period.

We also use 'energize-to-trip' on our unit fuel shutdown circuit and back up this electric circuit with a pneumatic tripping of fuel valves. For example, with this arrangement, in event of a power failure or tripping

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* **Protecting Industrial Furnaces From Explosions** by Melvin L. Jones, ASME Paper No. 59-A-274.

****Boiler-Furnace Explosion Survey** by J. B. Smith, ASME Paper No. 59-A-303.

THE SCHEDULED PANEL	UNSCHEDULED PARTICIPANTS
M. L. Crull, Department of Water and Power, City of Los Angeles, California	**H. H. Bickel,** Wickes Boiler Company
A. B. Dunn, Department of Water and Power, City of Los Angles, California	**P. C. Euchner,** Combustion Engineering, Inc.
M. L. Jones, Principal Power Engineer, E. I. Du Pont de Nemours & Company	**W. S. Tallon,** Electronics Corp. of America
R. Longstreet, Minneapolis-Honeywell Regulator Company	**John Hochuli,** Gibbs & Hill, Inc.
J. G. A. Mitchell, General Sales Manager, Panel Systems, Combustion Control Div., E. C. A.	**W. F. Lange,** Peabody Engineering Corp.
A. P. Olches, Chief Engineer, Peabody Engineering Corp.	**E. G. Peterson,** Peabody Engineering Corp.
C. E. Savage, Engineering and Construction Div., American Cyanamid Company	**K. Blaine,** Electronics Corp. of America
J. B. Smith, Chief Engineer, Factory Mutual Engineering Division	**A. L. Thompson,** McGill University
L. C. Walter, Republic Flow Meters Company	**J. E. Volpe,** Peabody Engineering Corp.
A. W. Hindenlang, Combustion Engineering Inc.	

Forum — Conference I; Boiler Safeguards

Arthur Dunn (*continued*)

device coil failure, the fuel valves can be closed penumatically. I would like to point out that our boilers are of the large utility type, remote manually operated with standard automatic shutdown circuits and should not be confused with those industrial boilers which must be considered as completely automatic.

As a result of using the 'energize-to-trip' design, we are not experiencing nuisance shutdowns from coil failures such as would occur in the 'de-energize-to-trip' circuit."

M. L. Jones . . .

"Here is the old, old story of the large utility vs the industrial. The industrial cannot afford or will not afford the dollars for backup devices. These devices and their controls can cost as much as the boiler!"

Arthur Dunn . . .

"Surprisingly enough, the pneumatic backup trip feature of our fuel shutoff circuit is very simple and inexpensive. Since our fuel shutoff valves are pneumatic diaphragm motor operated through latch type solenoids, the addition of the pneumatic trip amounted only to the mounting of a pneumatic operated three-way valve on the fuel valve and running of a single instrument pneumatic line to the control center."

M. L. Jones . . .

"We've burnt up coils. We'd buy solenoids built for 115 volt service and find out we're running under 125 volt conditions because the substation in a new plant has its transformers so lightly loaded. Under this voltage override, the coils just don't stand up."

A. W. Hindenlang . . .

"Would the class of service under which the boiler operates influence the degree of protection you would design into your boiler controls? In other words would you use energize to trip valves in an installation subject to frequent power failures?"

C. E. Savage . . .

"You are suggesting perhaps that we should take chances. What is the insurance company attitude on energize to trip or de-energize?"

J. B. Smith . . .

"With most industrials it is not necessary to energize to trip."

R. Longstreet . . .

"Do you object to energize to trip?"

J. B. Smith . . .

"We see the large utility boiler as a special problem."

A. W. Hindenlang . . .

"How about an industrial installation exposed to frequent power outages? What would the insurance company recommend?"

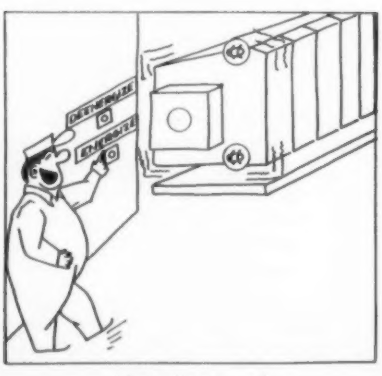
J. B. Smith . . .

"Frequent outages are, of course, intolerable. As Mr. Jones has suggested on this point on other occasions you must go to some auxiliary power source."

Editor's Note: A significant point was made here which has long escaped most of us. The apparent gulf between industrial and utility thinking on this problem decants to one vital item—dollars. In the industrial field there exists a strong feeling that we cannot spend the same sums for protection that the utilities afford. We ask the reader to follow this lead as the discussion develops, and to note particularly the projected cost of the equipment industrial users are considering to avoid trips due to power fluctuations. It seems to us that in this case the utilities may have the lower cost solution.

Auxiliary Power Supply Systems

M. L. Jones . . .



"Eenie, Meenie . . ."

"We've tried four auxiliary systems over a period of time. These are: steam-driven auxiliary generator, auxiliary generator connected to forced-draft fan with throw-over switching, inverter to convert d-c electricity from batteries to a-c for operation of safety equipment, convert all controls and valves from alternating current to direct current.

In the case of the auxiliary-driven generator, two units would be required, and if they are not properly maintained, reliability can be considerably less than public utility power.

With fan driven generators the problem of maintenance is major in that the generator requires a shutdown of the unit which is undesirable. In addition, the problem of throwover switching from purchased power to generator without a power failure requires momentary paralleling which is no simple electrical problem.

The inverter appears to be highly desirable in that existing standard units such as solenoid valves, relays and the like can be used. The problem is the procurement of a reasonably priced a-c to d-c to a-c power unit. Rotating equipment of this type is relative expensive and requires a spare unit for reliability. The use of static converters and inverters with an

auxiliary battery system for standby service appears to be a good possiility.

The newest seems to us to be the most attractive. Our first static converter (a-c to 26 volt d-c) goes on a unit soon. We float a battery on the 26 volt system connected to an inverter. We've tested its reactions to overloads, high voltage, other anticipated trouble points in the manufacturer's plant. It has a cut-off characteristic that lops off the tops of the sine wave. Yet we don't think it will trouble our instrumentation. We would like an electrical bypass so that we could pull out the inverter if it needs servicing. We're working on that aid right now. To use the battery is the most reliable system of power."

James G. A. Mitchell . . . "How about the cost of this unit? How much power does it need?"

M. L. Jones . . . "About $3000. The inverter draws up to 2000 watts of amplification. We are requiring the manufacturer to tell us how much inrush current can be safely handled by the unit's solenoids, other operating characteristics so we can know for sure the power we need."

James G. A. Mitchell . . . "As I understand it you would prefer to use this equipment, this inverter-battery scheme, than go to all d-c equipment."

M. L. Jones . . . "Oh, yes. Too many of the control devices are a-c actuated and d-c counterparts just don't exist or would be too difficult to stockpile."

James G. A. Mitchell . . . "How about this . . . Now at the instigation of Du Pont we developed a d-c flame safeguard device."

M. L. Jones . . . "Flame failure devices go out of service with voltage surges so at one time as part of our program we asked that a flame failure device for our units be designed for d-c and for 3 years have been hunting for someone to make us a static converter."

James G. A. Mitchell . . . "We have built or had designed systems wherein the converter rides over surges and the valves and similar equipment operate under d-c with the instrumentation left on a-c. As a rule of thumb the preference over the country for the d-c system calls for a 12 to 50 volt level. Your static converter is most interesting.

This protection of the flame failure device puts us in mind of an installation in Pottstown, Penna., where they suffered from power outages."

M. L. Jones . . . "We are talking about power surges, not outages. The surges are recurring things and they are the ones we try to guard against."

James G. A. Mitchell . . . "We are investigating rotary equipment such as the Waukeska emergency gasoline-driven generator. A Cleveland manufacturer for about $3000 to $4000 will provide a similar rotary device to float on the line, powered from the local public utility and equipped with a flip-over switch to batteries."

M. L. Jones . . . "What steps do you take to overcome the paralleling problems of frequency, voltage? We have tried several of these systems and as far as we are concerned a rotary is just another piece of equipment."

Editor's Note: We agree in general with Mr. Jones' comments above with two exceptions. The proposed a-c to d-c system represents additional equipment which Mr. Jones himself opposes in principle. Furthermore, while this new system holds greater promise of more reliable service than any the industrials have used in the past, it strikes us that the utility solution—backing up energize to trip valves with a single main pneumatic trip (plus overvoltage protection for surges) is actually a lower cost proposition.

What to Do on a Flame Failure Signal

Having considered the mechanics of tripping, (cutting off the fuel supply to burners) the question of when and what to trip inevitably arose.

M. L. Jones . . . "With multi-burner jobs you can monitor each burner. The only way you would shut off all burners is if the main fuel supply was lost."

A. W. Hindenlang . . . "Is it wise to trip out an individual burner in a multi-burner installation?"

Arthur Dunn . . . "We use quick-closing devices for both fuel valves and air registers. But with multiburner furnace loads of 50 per cent and up, flame failure is rare. If an individual burner goes out, its neighbors support it."

J. B. Smith . . . "Is this observation just for gas and oil?"

Arthur Dunn . . . "Yes."

James G. A. Mitchell . . . "The different fuels require different conditions. Large units mean you must consider burner configurations. There are different conditions on each set-up. Utility boilers have an entirely different set of conditions."

J. B. Smith . . . "Going back for just a moment what makes Mr. Olches think that with 4 burners and losing one that the air going through that dead burner will wind up mixing properly? Any instruments to support that conviction? Was the situation he knows about under instrumented conditions or just normal operation?"

A. P. Olches . . . "Instruments that could be used to determine safety in this situation are O_2 recorders, combustible recorders and of course physical observation."

James G. A. Mitchell . . . "This is a common problem with a fast shutoff. You now send 100 per cent of the fuel you need to hold the load through 3 burners with one dead, but 100 per cent of the air through 4 registers. The mixture is not an ideal one and some may consider it improper but does it create a dangerous or an emergency condition?"

A. P. Olches . . . "No. As a general procedure you close off fuel before air. The only time, then, that you would have a dangerous condition is at low loads."

E. G. Peterson . . . "Furnace design usually permits some intermixing and turbulence."

John Hochuli . . . "Excess air, to me, at any time is a hazard. What are the insurance

companies finding? Could you give me any statistics which would point to one or the other, a lean or a rich mixture, as the worse one?"

J. B. Smith . . .

"Explosions occur under both conditions. To speak absolutely we would have to know the conditions at the moment of explosion. We rarely if ever do. We have to piece together the story. Furnace surroundings, burner design, all enter into our guess on what could have caused the problem. The industry as a whole relies too much upon visual examination, guessing, and shows too little inclination to use scientific techniques to pinpoint the causes of furnace explosions."

M. L. Jones . . .

"Too much excess air can blow out the fire and the resulting upset in furnace conditions will set the stage for trouble."

H. H. Bickel . . .

"At both ends of the fuel-air ratio you can expect trouble—too rich and no fire, too lean and no fire. But too rich a mixture is less dangerous in my opinion."

"Instruments to determine safety are O_2 recorders . . ."

. . . but does it create a dangerous condition?"

Editor's Note: At first reading this part of the discussion appears to lead nowhere and no significant area of agreement appears. However, on closer reading it becomes obvious that both high and low excess air create hazards and that individual burner trips are not necessary—may rather be dangerous—where it is established that burners support each other. In other words in burner arrangements and/or at ratings where unignited fuel issuing from a burner will be reliably ignited by adjacent burners it may well be safer to sound an alarm than to trip the burner. Though industrials tend to frown on this approach they are actually agreeing to it by their acceptance of the policy that a flame safeguard device need not discriminate (i.e., be activated only by its own burner) above 50 per cent of maximum firing rate.

Our report on the Flame Safeguard Conference will be completed next month. Flame sensing, flame failure, application of flame safeguards and purging are some of the topics covered in Part II

Economical Power Plant Operation

By low-cost, all-water year-around transportation on the inland waterways and Great Lakes and by rail shipments, United Electric is delivering this year millions of tons of washed coal to satisfy the requirements of large industries and electric public utilities in the middle west.

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The boiler feed pump and its associated equipment represent a major operating and maintenance consideration in today's power plant. Here we run in question and answer form a series of clinic sessions on various boiler feed pump problems. The replies are the work of one of the topmost pump authorities and give specific information which we hope will prove valuable to our readers.

By IGOR J. KARASSIK*

Worthington Corp.

Steam and Power Plant Clinic—Part XV

QUESTION

I have enjoyed reading the series of articles by Mr. Karassik in the issues of COMBUSTION *beginning with August 1958, under the general title "Steam Power Plant Clinic." I am writing to point out that the piping arrangement shown in the September 1958 issue Fig. 1, for a common spare pump serving two separate units is inherently hazardous if care is not taken to prevent misoperation of certain valves. If, by some misoperation, gate valves Nos. 1 and 2 were closed, the gate valve in the line entitled "Drain to Lower Pressure" were closed and the discharge gate valve of the pump were open, it would be possible for the boiler feed discharge header pressure to back up through the pump and be imposed upon the entire pump and its suction piping.*

I would suggest that a small relief valve be installed on the pump suction line to warn of excess pressure in the suction line and to relieve this pressure. I would also suggest that a gate valve be installed in the little orifice bypass line for more reliable isolation of the pump for maintenance if the gate valve in its discharge line could not be closed off tight and should leak slightly. A possible substitution for the relief valve would be to lock open the gate valve in the drain to lower pressure.

ANSWER

I will not deny that certain hazards exist from misoperation of the system shown in the piping diagram in the September issue and reproduced here, Fig. 1. Unfortunately, misoperation hazards will probably always be with us until the day that a steam power plant is built which is completely automatic in its operation and in which no human hand or human judgment is permitted to interfere with a prefabricated programming. Even then, I fear, the plant will not be one hundred per cent free of random failures: witness the record compiled in the launching of our rocket-powered satellites! I have frequently said that there is *always* a risk to operating a steam power plant. Once we admit this to ourselves and devote our efforts at *reducing* this risk rather than to *eliminating it*, we will make progress. Otherwise, we will be chasing an elusive and unattainable will-of-the-wisp.

And so it is in this case. If we assume that through misoperation the gate valve in the drain line is closed, it is obvious that pressure would build up in the pump—except for whatever relief is afforded through leakage past the stuffing boxes. Your other two assumptions are actually not necessary, since they are facts: gate valves No. 1 and 2 *are closed* and the discharge gate valve *is open*, not through misoperation but rather through intent, as indicated in the body of the article. Thus, the closing of the drain valve would be a major error in operation.

As to the provision of a relief valve, I feel that it is optional rather than mandatory. I know of installations where such relief valves are not used merely on the theory that infrequently operated relief valves may be as hazardous as the misoperation against which they are

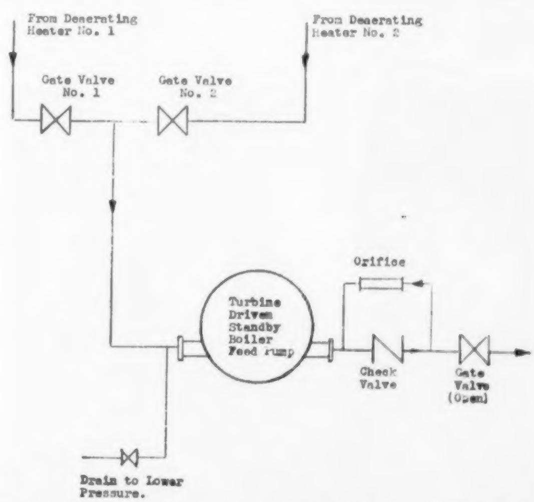


Fig. 1—Arrangement of a standby boiler feed pump serving two units as shown in Sept. 1958 *Combustion*

* Consulting Engineer and Manager of Planning Harrison Div.

intended to provide protection. For instance this is most often true of the balancing device leakoff line of high pressure boiler feed pumps which returns to the deaerating heater at the pump suction. This line is always provided with a gate valve to permit isolating the pump for inspection or complete dismantling. Closure of this valve through misoperation would cause a major catastrophe to the pump—and yet, few such leak-off lines are protected by relief valves against such an emergency. Thus, for my part, I would prefer locking the drain valve in the open position while the common spare pump is out of operation.

As to the valve in the small jumper line around the check valve, I agree entirely with you with regards to its necessity. I had merely oversimplified the diagrammatic sketch. In the system drawings that we supply our customers for this portion of the auxiliary hook-up, the isolating valve is always shown. It is, however, kept in the locked open position until such time that a pump is to be opened for inspection.

QUESTION

In one of your recent articles under the title of "Steam Power Plant Clinic," you discussed the possibility of measuring wearing ring clearances of axially-split casing boiler feed pumps without dismantling the rotor. The procedure you recommended is not, of course, applicable to radially-split casing barrel type pumps, since these have to be completely dismantled for inspection. Such an inspection, of course, also affords the opportunity to examine the wearing ring surfaces for burrs, grooves or other irregularities.

I would like to ask you how accurately do you feel wearing ring clearances of such pumps should be established on inspection—in other words, should they be measured to within one-thousandths of an inch, or closer or less closely?

ANSWER

Boiler feed pump clearances on new high pressure boiler feed pumps will range from 0.012 to 0.018-in. on the diameter and the normal practice is not to renew these clearances by replacing the wearing rings until these clearances have about doubled from wear. Certainly it is not necessary to measure clearances closer than to one-thousandth of an inch. On the other hand, it should prove to be no problem to measure these clearances to such a tolerance of measurement.

The normal procedure in carrying out this inspection is to measure independently the I.D. of the wearing ring fit and the O.D. of the impeller wearing ring hub, using inside and outside micrometers respectively as shown in Figs. 2 and 3. Several measurements should be taken, to determine whether or not the wearing ring or the impeller have not been wearing out in an egg-shape manner. The clearance is considered to be the maximum I.D. and the minimum O.D. readings.

Certain maintenance mechanics measure the clearances directly, by placing the impeller within the wearing ring, as in Fig. 4 and moving it laterally against a dial indicator to determine the diametral clearance. In order to discover any inequality in wear around the circumference, the impeller should be rotated and the dial indicator should be attached to several points of the stationary part. In my opinion, the "difference" method is more reliable.

One important warning is that the impeller and wearing ring should be at the same temperature before the readings are taken. Many designs use shrunk-on impellers which have to be heated prior to removal from

Fig. 2—Measuring I.D. of wearing rings

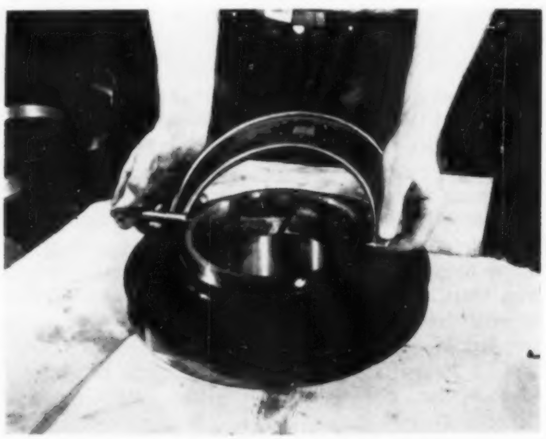


Fig. 3—Measuring O.D. of impeller hub

the shaft. The impeller may thus be heated to at least 400 F and possibly to as much as 500 to 600 F. Chances are that it will be allowed to cool down to something like 120 F so that it can be handled comfortably before the measurements are taken. But if the wearing ring is at, say, 80 F, there will be a 40 F difference the two parts and this difference can be quite significant. If the coefficient of thermal expansion is taken as 0.0000065 inches per inch per degree F and if the wearing ring fit diameter is 8-in., the apparent clearance will be about two-thousandths of an inch less than the true clearance. This error will, of course, be magnified if the impeller diameter is measured when the temperature of the impeller is even higher than the 120 F we have assumed.

This possibility of error is one that is frequently overlooked in the measurement of clearances in general, as our first reaction is to assume that such a small difference in metal temperatures cannot be of any consequence.

Fig. 4—Measuring wearing ring clearance by moving impeller within clearance

Act Now for Future Engineers

The United States must decide and take action now to insure the availability of enough engineers and the right kind of engineers to meet the expanding demand for technical services of the 1960's, according to a report by the Engineering Manpower Commission of Engineers Joint Council, recently reported in the Spring, 1960 issue of *Engineer*.

The report follows the announcement by the U. S. Office of Education that freshman engineering enrollment has declined for the second consecutive year, over 3 per cent in 1959, after an 11 per cent drop in 1958. This, says the Manpower Commission's report, is an unexpected trend when demand for engineers is increasing and is expected to accelerate, especially when the nation is committed to a world contest depending largely on a sufficient supply of engineering brainpower.

The Engineering Manpower Commission points to these factors:

Because of enrollment drop, for the next five years we may expect 37,500 engineers to graduate each year, against pre-1958 predictions of close to 43,000.

Only 2 per cent of the coming college-age group will be available for engineering.

Between January, 1953 and January 1959, engineers rose from 409,000 to 630,000 an increase of 221,000 or more than all engineering bachelor degrees awarded.

Business cycle changes have only a temporary effect on demand for engineers.

By 1966 more than 2 engineers will be hired for every one this year.

The Gross National Product, closely related to productivity, depends on the supply of engineers.

The Manpower Commission concludes that two basic objectives must be met: (1) best use of available engineering manpower and (2) sufficient engineering graduates.

To meet the objectives, the Commission advocates: insuring that engineers and engineering technicians are used to their best capacity in industry, government and education; increased recognition of engineers at government level; make it possible for engineers to discharge their service to the nation as either civilian or military in the best public interest; improve quality of *all* education; improve public relations of engineers and engineering through parents, students, guidance counselors, industry and government.

According to Julian W. Feiss, Chairman, "The Commission will strive toward the achievement of these objectives and will issue statements to further amplify these long-term views. We invite the support and cooperation of other organizations and individuals with the vital problem of fully developing our engineering manpower resources."

The Commission's report, entitled "Engineering Manpower and the National Interest" is available in quantity at Engineering Manpower Commission.

AEC Reports on Nuclear Power

The Atomic Energy Commission is publishing a multiple-volume report on the status and potential of civilian nuclear power reactors, and its plans for future development.

The three parts released are: Part I—Summary of Technical and Economic Status as of 1959; Part II—Economic Potential and Development Program; Part IV—Plans for Development.

Part III—Technical Status Reports, summarized in Part I, will be made up of seven or more volumes, and is scheduled for publication starting in April. Each volume of Part III will describe the technical status as of 1959 of a particular reactor concept. The availability of these volumes will be announced at a later date.

Parts I and II have been previously available in draft form in the Commission's Public Document Room, 1717 H street, N. W., Washington, D. C. Portions of Part III have also been available in the document room.

Abstracts From the Technical Press—Aboard and Domestic

(Drawn from the Montely Technical Bulletin, International Combustion, Ltd., London, W. C. 1)

Fuels: Sources, Properties and Preparation

Coal Science. I. G. C. Dryden. *Nature* 1959, **184** (Aug. 8), 412–14.

Summaries are given of papers presented to the 3rd biennial International Conference on Coal Science held at Valkenburg, Holland, on Apr. 27–30, 1959. Research into chemical reactions of coal, ultra-fine structure of coals and chars, spectroscopy of coals and carbonization was described.

Studies of Coal. Staff of B.C.U.R.A. *Nature* 1959, **184** (Aug. 8), 425–7.

The first article deals with carbonization of coals in the presence of activated charcoal and the second with smoke emission from coal and low-temperature chars.

Rate of Discharge of Granular Materials from Bins and Hoppers. H. E. Rose and T. Tanaka. *Engineer* 1959, **208** (Oct. 23), 465–9.

From results obtained on models an equation has been derived for the calculation of the rate of discharge of most materials from bins and hoppers of normal type. The accuracy of the calculation is considered sufficient for all practical applications.

Heat: Cycles and Transmission

Heat Transfer at High Pressures. Anon. *Engineering* 1959, **188** (Oct. 2), 286–7; (Oct. 9), 317–9.

Research on heat transfer in nuclear power boilers operating with hot gas at 10 and 20 atm pressure is reported. Both an open and a closed circuit were used and results are presented for the latter. A general relation for the Nu number could be established.

Heat Transfer and Draft Loss in the Tube Banks of Shell Boilers. D. J. I. Roderick, M. V. Murray and A. G. Wall. *J. Inst. Fuel* 1959, **32** (Oct.), 450–63.

Tests on an Economic type boiler were carried out to determine the accuracy of dimensionless equations for the heat transfer by forced convection from hot gases flowing through water-cooled tubes. The effect of inserting retarders on draught loss in the tubes has also been investigated. Appendix 1 presents an evaluation of draught loss, Appendix 2 the results of tests with turbulence promoters or retarders and Appendix 3 design curves for shell boiler tube banks.

Steam Generation and Power Production

About Calorific Properties of Water under Pressures up to 500 kg/cm² and Temperatures up to 300 C. A. M. Sirota and E. P. Beliakova. *Teploenergetika* 1959 (Oct.), 67–70 (in Russian).

New experimental data of C_p of water are compared with those of other authors and with calculations from p-v-t data. The enthalpy of water is calculated up to 500 kg/cm² and 300 C.

An Experimental Investigation into Thermal Conductivity of Water. N. B. Vargaftik and O. N. Oleschuk. *Teploenergetika* 1959 (Oct.), 70–4 (in Russian).

Values obtained by experimental investigations are tabulated for the temperature range 20 to 350 C.

An Experimental Determination of Specific Volumes of Water up to 1200 kg/cm.² M. P. Voukalovich, V. N. Zoubarev, A. A. Alekdsandrov and U. J. Kalinin. *Teploenergetika* 1959 (Oct.), 74-7 (in Russian).

Experimental data are presented of specific volumes of water at pressures up to 1200 kg/cm² and temperatures up to 300 C and compared with results of earlier investigations.

Experimental Investigation into the Effects of Cross Flow with Condensation of Steam and Steam-Gas Mixtures on a Vertical Tube. T. Furman and H. Hampson. *Proc. Inst. Mech. Engrs.* 1959, **73,** No. 5, 147–69.

As part of a study of film and dropwise condensation of steam an experimental investigation was carried out into the effect of cross flow velocities of steam, containing some non-condensable gas, on the overall and steam side coefficients for the steam condensing on a tube with either filmwise or dropwise mode. The results are presented and discussed.

The Big Waste Burning Plants are a Source of Heat and Power. J. H. D. Blanke. *Pwr. Engng.* 1959, **63** (Sept.), 96–9.

Disposal of waste by incineration is growing rapidly in the U.S.A. and many plants use the heat to generate hot water or steam for various purposes. On average 1.2 lb. of steam can be produced from 1 lb of waste. Several modern incinerator and waste heat utilizing plants are described.

The Shell Boiler: An Historical Review: M. V. Murray. *J. Inst. Fuel* 1959, **32** (Sept.), 425–33.

Fuel Firing

Choice of Coal Preparation Systems for Pulverized-Fuel Firing. J. M. Beer. *Engng. Boil. Ho. Rev.* 1959, **74** (Sept.), 274–9.

The direct and indirect (open and closed circuit) methods of pulverizing and transporting the coal to the burners are compared. Equations are developed to obtain criteria for the application of one or other of the methods.

Automatic Stokers. Anon. *Engineer* 1959, **208** (Oct. 23), 487.

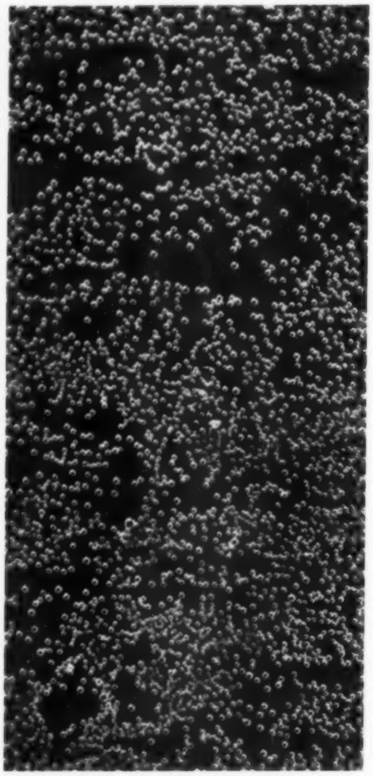
A water-cooled precombustion chamber for shell-type boilers has been introduced to this country from the Continent which differs in essential details from other designs. The coal is moved by a screw conveyor to the top center of the chamber and drops through a vortex chamber and in a thin layer on the grate of the combustion chamber. One third of the combustion air is injected through the grate, one third in a tangential direction through a duct in the vortex chamber and one third into the combustion gases at the throat between the combustion chamber and boiler. All types of coal with an upper size of 1 per cent, maximum fines content of 35 per cent below $^1/_8$ in. and maximum moisture content of 15 per cent can be burned. A consistent CO_2 figure of $^{14}/_{16}$ per cent without smoke production is obtainable.

Unit Wide-Ram Coking Stoker. Anon. *Engng. Boil. HO. Rev.* 1959, **74** (Sept.), 279–80.

A new stoker has been introduced which fully complies with the Clean Air Act and can be used in all shell type and small water-tube boilers. It has infinitely variable hydraulic speed control of the grate and feeding mechanism.

Chain Grate Ash Extractor. Anon. *Engineer* 1959, **208** (Oct. 16), 441.

A new extractor has been developed by Riley (I.C.) Products Ltd. for use with the "T" chain-grate stoker. The conveyor has apron plates on



which the ash is carried to the front ash box and is driven by a $\frac{1}{8}$ hp geared motor to give it a speed of $3\frac{1}{8}$ ipm. The conveyor incorporates a steam cleaning device to remove fine ash particles.

Pressure-jet Oil Burners for Boiler Use. A. M. Brown. *J. Inst. Fuel* 1959, **32** (Sept.), 409–17.

The development of this type of burner is reviewed. It is stressed that present day knowledge of high combustion intensity, liquid sprays, furnace aerodynamics and flame stabilization is insufficient and requires intensive research, if possible by model studies, to obtain higher combustion efficiencies, larger turndown rates and higher efficiencies.

Furnaces and Combustion

Combustion. R. Friedman and J. H. Grover. *Ind. Engng. Chem.* 1959, **51** (Sept.) (Pt. II), 1067–74.

The annual review of the literature for 1958.

An Investigation into Radiant Heat Exchange in the Furnace of a Steam Generator Burning Natural Gas. F. P. Kazakevich, A. M. Krapivin, G. I. Anofriev and I. G. Vesley. *Teploenergetika* 1959 (Oct.), 34–8 (in Russian).

The experimental data are compared with results obtained by calculation and the good agreement is noted.

Similarity Criteria for the Study of Furnace Flames by Means of Cold Models. G. G. Thurlow. *Comb. and Flame* 1959, **3** (Sept.) 373–88.

The conditions necessary for obtaining similarity between a model and a furnace are considered in detail and criteria developed for the conditions under which these can be applied. Criteria are derived for two cases dependent on whether the momentum of the secondary air is appreciable or not. Tests on a small gas-fired and a cold model of similar dimensions are reported. Reasonable agreement of the order $\pm 20\%$ between the mixing of fuel and air in a hot and a cold furnace is thought to be attainable.

Laboratory Investigations into the Behavior of Fuels in Furnaces. K. Wickert. *B.W.K.* 1959, **11** (Oct.) 455–62 (in German).

The experiments concerned the combustion velocity of carbon and sulphur alone and together as a function of temperature, time and particle size, of gases containing H_2S, CO, H_2, CH_4 and O_2 as a function of temperature and excess air, and of oil coke as a function of pretreatment temperature (volatile content). The results show that the fly ash particles contain a C-S compound of unknown composition which is very stable up to temperatures of about 1300°C. It follows that in furnaces with relatively low temperatures (dry ash removal) most of the sulphur in the coal is carried away in the fly ash, whilst in furnaces with high temperatures (liquid slag removal) much of the sulphur is liberated and able to form new compounds with oxygen, hydrogen and the mineral constituents of the ash. From temperatures of 1 200°C upwards S reacts with SiO_2 and alkali forming silicon disulphide, alkali sulphates and alkali pyrosulphates of which the latter are mainly responsible for deposit formation and corrosion.

Power Generation and Power Plant

I.E.E. Local Centres. Anon. *Electr. Times* 1959, **136** (Oct. 15), 400–1.

In his address "Past, Present and Future" the chairman of the North-Western Centre, F. J. Hutchinson, discussed the future of thermal power stations. He believed that 800 MW sets would be built with steam conditions of 5000 psi and 1200/1500 F within the next 10 years. The heat rate would decrease by 6.7 per cent, compared with 2350 psi and 1050/1000 F, to 8400 Btu/kwhr. Boilers would be of the forced-flow once-through type with pressurized furnaces and liquid slag removal. Capital cost per kw installed would then fall to below \$112 compared with \$117.60/kw for Thorpe Marsh. Mr. H. Watson Jones, the chairman of the North-Eastern section, gave some details of the Trawsfynydd nuclear station and the advances made in design compared with the earlier stations.

11th Steam Station Cost Survey. Anon. *Electr. Wrld.* 1959, **152** (Oct. 5), 71–86.

The comparison of various data of steam power stations operations and costs between 1956 and 1958, given in tables and graphs, shows that the average cost of energy production has decreased from 7.15 mill to 7.04 mills per net kwh, construction costs from \$146/kw to \$140.6/kw, fuel costs from 83 to 80.8 per cent, average annual plant factor from 69 to 61.8 per cent and utilization factor from 103 to 100.4 per cent. The predominant steam parameters remained constant at 1800 psi and 1000/1000 F and use of reheat decreased from 80 to 70 per cent. The average station heat rate continued to decline and now stands at 10,934 Btu/net kwh. Installations of outdoor plant has made further progress and boiler room volume decreased from 12 to 11 cu ft/kw.

Central Station Design Survey. Anon. *Power* 1959, **103** (Oct.), 179–90.

Block diagrams and tables give details of conventional and nuclear power station units which were commissioned or under construction during 1959. (1) Boiler sizes are remaining fairly constant with a trend to pressures of 2400 psi, although 1800 psi is still predominant; (2) pulverized coal continues to be the main fuel; (3) pressurized furnaces are gaining ground; (4) heat release rates of 16,000 to 20,000 Btu/cu ft/h predominate.

Steam Turbine Cycles in Power Stations. K. Fenton. *Electr. Rev.* 1959, **165** (Oct. 2), 373–7.

The improvement in cycle efficiencies achieved in recent years is reviewed with reference to non-reheat, reheat and supercritical pressure plants. The dual-pressure cycle used in gas-cooled nuclear power stations is also discussed.

Efficiency of Steam Generation. J. N. Williams. *Pwr. and Wrks. Engng.* 1959, **54** (Sept.), 515–25.

The setting up of a heat balance is discussed and the investigations required additionally for this purpose described. Examples of application are given.

Industrial Plant Design Survey. Anon. *Power* 1959, **103** (Oct.), 105–19.

Block diagrams and tables give a survey of trends during the past year: (1) Boiler size; (2) fuels (mainly gas-oil combination); (3) firing equipment; (4) heat release rates; (5) controls; (6) feed water treatment; (7) dust collectors; (8) air heaters and ash handling systems.

New Ways to Make In-Plant Generation Pay. Anon. *Power* 1959, **103** (Oct.), 80–5.

The following problems are discussed and examples of solutions described: (1) Steam and electric power generation can be balanced by the installation of air conditioning plant for use at times when the heating load is low; (2) waste heat recovery by burning bark and wood waste previously discarded, by utilizing CO gas from burning off cracking-unit catalyst in specially designed boilers with or without supplementary fuel, from metal refining plants, cement kilns, steel mill processes and petroleum refineries for which packaged waste-heat boiler have been designed; (3) packaged boilers of smaller capacity are shipped as a unit, for capacities of 80–450 klb/h in prefabricated sections resulting in 25–30 per cent savings in erection costs.

More Power for Nation's Capital. Anon. *Coal Utilisation* 1959, **13** (Sept.), 14–7.

The peak load of Washington, D. C., now occurs in summer with a load of 1156 Mw compared with a winter peak of 822 MW. To satisfy this demand a new unit has been installed at Dickerson station, Maryland, consisting of a 1300 klb/h boiler operating at 2485 psi and 1050/1000 F and a 175 mw cross-compound turbine generator; an identical second unit is under construction. The boiler is of the wet bottom type and contains 32 tilting tangentially firing burners served by 4 bowl mills, each rated at 38,000 lb/h, 66 sootblowers, two air preheaters and an electrostatic precipitator. Furnace ash removal is hydraulic, fly-ash removal pneumatic. The net heat rate is calculated at 8700 Btu/kwh.

A Boom in Paradise. Anon. *Electr. Wrld.* 1959, **152** (Oct. 12), 90.

The first completely new power station to be built by TVA since 1953 will be located at Paradise, Ky. It will contain four 600 MW units, the first to be commissioned in 1962. Peabody Coal Co. will supply 65 million tons of coal over a 17-year period at a price one-fourth less than the average price TVA are paying now. GE is to supply the turbo-generator, CE probably the steam generator.

Philo 6 Produces Design Data as well as MWhr. Anon. *Power* 1959, **103** (Oct.), 164–7.

Experience gained during 30 months running of this supercritical pressure unit is reported. (1) Severe corrosion of turbine bypass valves eliminated by design changes; (2) boiler feed pumps sealing trouble requiring new design of seals; (3) plant heat rate in tests was 8954 against design figure of 8759 Btu/kwh, due to higher power consumption of feed pumps; (4) slagging in the secondary furnace affecting also the gas recirculating parts was met by installing additional soot blowers but was not yet wholly successful; (5) cracking of dissimilar welds occurred where also the cross-section was changed from $4^1/_2$ to 5 in.; these welds were replaced by shop-fabricated joints; (6) cracks in attachment welds on stainless steel required removal of all attachments where possible, grinding out and re-welding or plugging and welding; (7) heavy deposits in the turbine contained mainly cuprous and cupric oxides and iron oxides; increasing the pH level by addition of ammonia has given best results in reducing copper pick-up but this continues to affect the turbine; to obtain minimum

copper concentration in the cycle, starting takes up to three days.

Bold "B" Generating Station. Anon. *Electr. Rev.* 1959, **165** (Sept. 11), 209–15.

This station will contain, when completed, 3 units each consisting of a boiler rated at 550 klb/h at 950 psi and 925 F and a 60 MW turbogenerator. The ash in the furnace hoppers is removed by a dry vacuum system to to container-filter units where the air is separated and from which the ash is discharged after conditioning with water into ash lorries. The ash is used for making building bricks and for constructional purposes at the Rheidol hydroelectric plant and the Ffestiniog pumped storage project. The first generator is hydrogen-cooled at 15 psi, the second and third at 30 psi and the stator of the latter is water-cooled.

Grits Galore—A Kingston Experiment. K. S. Matts and D. Turner. *Electricity* 1959, **12** (July/Aug.), 270–3.

The coke breeze fired at Kingston power station on chaingrate stokers led to the production of a large amount of grits with a combustible content of 60–80 per cent. Experiments in briquetting the grit and to refire it are described. The first briquettes produced proved to be too large and further experiments with smaller briquettes ($^1/_4'' \times {}^3/_4''$) are to be made.

Contracts Signed for 52-Utility Nuclear Project. Anon. *Electr. Wrld.* 1959, **152** (Sept. 7), 47.

The contracts signed between AEC and Philadelphia Electric Co. and General Dynamics Corp. are for a 40 MW (*e*) high-temperature gas cooled reactor to be commissioned in 1963. The fuel elements of the second core will contain slightly enriched uranium and thorium mixed with graphite in homogeneous carbon compacts, but the first core will have metal clad elements limiting the steam temperature to 850 F; the second core should allow a helium coolant temperature of 1382 F and a steam temperature of 1000 F. The costs are estimated at $40 million.

Materials and Manufacturing Processes

The High Temperature Properties of Four Wrought Steels Used in the Chemical Industry. B. J. Connolly and G. Boyd. *Proc. Inst. Mech. Engrs.* 1958, **172** (No. 31), 889–900. Short-time high-temperature (up to 550 C) tests on low-carbon 1 per cent Cr-Mo, medium-carbon 1 per cent Cr-Mo, low-carbon 3 per cent Cr-Mo

and 18-10 Mo-Ti Cr-Ni austenitic steels were made to study their tensile and creep properties. The results are presented in tables and graphs.

Report of Project SP-4 to Steam Power Panel of the A.S.M.E.-A.S.T.M. Joint Committee on the Effect of Temperature on the Properties of Metals. J. S. Worth. *A.S.M.E. Preprint* No. 59-Met-12, 1959 (Apr.), 13 pp.

Short-time high temperature tensile and creep-rupture tests on SA 212 Grade B steel are reported. The effect of welding on high-temperature properties has also been investigated.

Plasma—A Substitute for the Oxy-Fuel Flame. J. A. Browning. *Weld. J.* 1959, **38** (Sept.), 870–5.

The fundamental properties of the plasma arc and the methods developed for its application are described. The gases to be used for forming the plasma are discussed; a plasma flame with non-transferred arc can reach a temperature of 30000 F with a heat transfer rate of 42 Btu/in.^{2}/sec. The operating costs of the plasma system are low, about half those of those using an oxy-acetylene burner.

Instruments and Controls

Temperature Control by Damper-controlled Flue Gas Passes in the Fortuna Power Station. R. Müller. *Mitt. V.G.B.* No. 61, 1959 (Aug.), 27, 4–6 (in German).

Superheated and reheated steam temperature control by spray desuperheaters and by damper controlled flue gas passes is compared and the advantages of the latter with regard to reheated steam temperature control discussed. The time until the new temperature is reached is about 10 minutes in both cases.

Control of Benson Boiler-Turbine Units. A. Fischer. *Mitt. V.G.B.* No. 61, 1959 (Aug.), 294–302 (in German).

The various possibilities of controlling a Benson boiler-turbine unit under fixed or fluctuating load with and without network frequency changes are discussed and the ability of the Benson boiler stressed to follow the changes rapidly without excessive fluctuations in temperature and pressure. The results of tests on a 190 t/h and 450 t/h Benson boiler are reproduced; the temperature fluctuations were in an extreme case ±5 C but generally did not exceed ±3 C and the pressure fluctuation maximum 7 atm but generally not more than ±4 atm.

The Measurement of Grit Emission. R. Jackson. *Steam Engr* **1959, 28** (*Sept.*), 368–74.

Principles of dust measurement in general are considered and the instruments developed by BCURA for isokenitic sampling described. The first first one contains a cyclone probe for returning the corase dust, the second one includes a filter for the additional retention of the find dust; both instruments are intended for the smaller boiler plant. The procedure to be followed to obtain isokenitic sampling is outlined.

Operating Safety Shapes Today's Control Systems. Anon. *Power* 1959, **103** (Oct.), 167–9.

Control of power station operation by computers or data-logging systems is believed to increase efficiency by $^1/_2$ per cent and these are being installed in increasing numbers. A new control panel of much smaller dimensions than previous ones has been developed for boiler-turbine control to facilitate the work of the operator; wherever possible indicators are replaced by annunciators; the greater compactness also increases safety.

Nuclear Energy

The Investigation of Controlled Thermonuclear Reaction in the USSR. C. A. Artsimovich. *Vestnik Akademii Nauk SSSR* **1959** (1), 11–23. *LLU Transl. Bull.* **1959** (*Sept.*), 28–41.

Research into thermonuclear processes in Russia is reviewed and the results obtained so far are described and discussed. The necessity for international cooperation in this field is stressed.

Atomic Review. Departures in Gas Cooling. Anon. *Engineering* 1959, **188** (Sept. 11), 156–8. Several reactors with different gas cooling systems to allow higher fuel and consequently higher steam temperatures are discussed. These include the Brown Boveri-Krupp pebble-bed reactor, the Canadian Daniels-Boyd reactor, the General Nuclear Engineering Corp., pressure-tube reactor, the ORNL intermediate-temperature reactor, high-temperature reactor of the Philadelphia Electric Co. and General Dynamics Corp. and the General Electric Co.'s land versions of the gas-cooled ship reactor.

The Economics of Gas-Cooled Reactors. G. S. Vincent. *Nucl. Pwr* 1959, **4** (Sept.), 88–92.

The factors involved in unit cost calculations, viz. capital charge, capital charge on fuel, fuel replacement costs, are discussed and curves are developed for various interest rates and

amortization periods. The graphs show also the effect of taking into account interest during construction, and enable the calculation of unit cost for any combination of capital cost, interest rate, amortization period, efficiency and load factor.

The Future of Gas-Cooled Reactors. W. S. Banks. *Nucleonics* 1959, **17** (Sept.) 96–102.

A coal burning combined gas and steam turbine and a gas-cooled reactor including a turbine driving a gas compressor are compared. It is suggested that to be competitive the reactor must operate at 2000 F with gas temperature above 1500 F and burnup above 15000 MW d/t, fuel costs of about 2 mills/kwh and a size of 1100–1500 MW (th). The fuel elements would be of UO_2, the moderator graphite and the gas helium. It is also assumed that the coal burning plant would operate at 1400 F and 7000–10000 psi.

Argonne Evaluates Process-Steam Reactors. Anon. *Nucleonics* 1959, **17** (Sept.), 112.

A pressurized-water boiling-water and organic moderated reactor to produce 125 klb/h of steam at 380 F saturated were compared as to costs and ease of control. On both points the PWR appears to be superior although the differences are not large.

Nuclear Marine Propulsion. A Review of Developments in America. J. R. Finniecome. *Mech. Weld* 1959, **139** (Aug.), 356–61.

A concise review with tables giving relevant data but it is stressed that detailed information on reactors and turbines are not available.

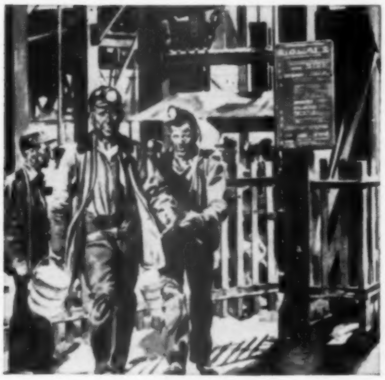
Soviet Fast Reactor—BR 5. R. R. Matthews. *Nucl. Engng.* 1959, **4** (Oct.), 359–60.

The reactor uses plutonium as fuel and sodium as coolant with an exit temperature of 450 C and an inlet temperature of 375 C. A breeding blanket has not been installed to simplify the design. Brief details are given of the core and shielding.

Development of Thermal Breeder Reactors. Anon. *Engineer* 1959, **208** (Sept. 25), 325.

The U. S. Atomic Energy Commission has decided to discontinue for the time being much of the work on the fluid fuel reactor program and institute instead a program of research on the conversion of thorium into a fissionable material as this would appear to be a more economic proposition. It is possible that part of the work on the fluid fuel reactor will be incorporated in the new research at a later date.

BEACON COAL HAS WHAT IT TAKES



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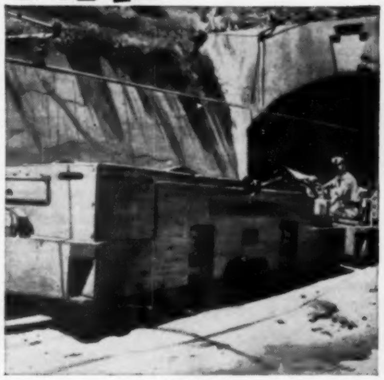

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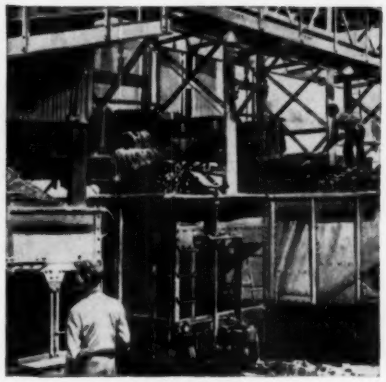

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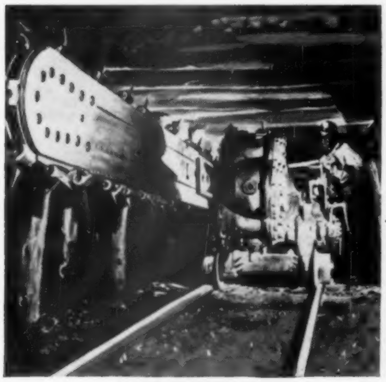

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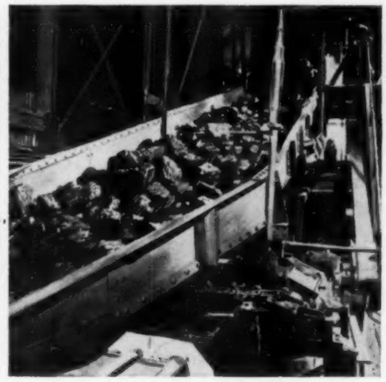

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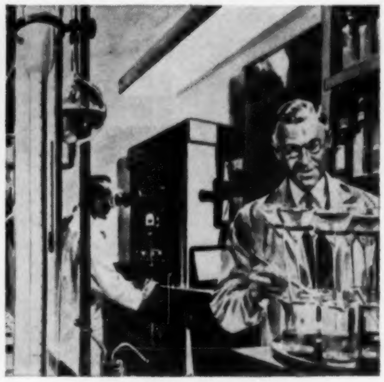

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(Continued on page 67)

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